

*a guide to alternative fuel vehicles*

APRIL 1996



CALIFORNIA  
ENERGY  
COMMISSION

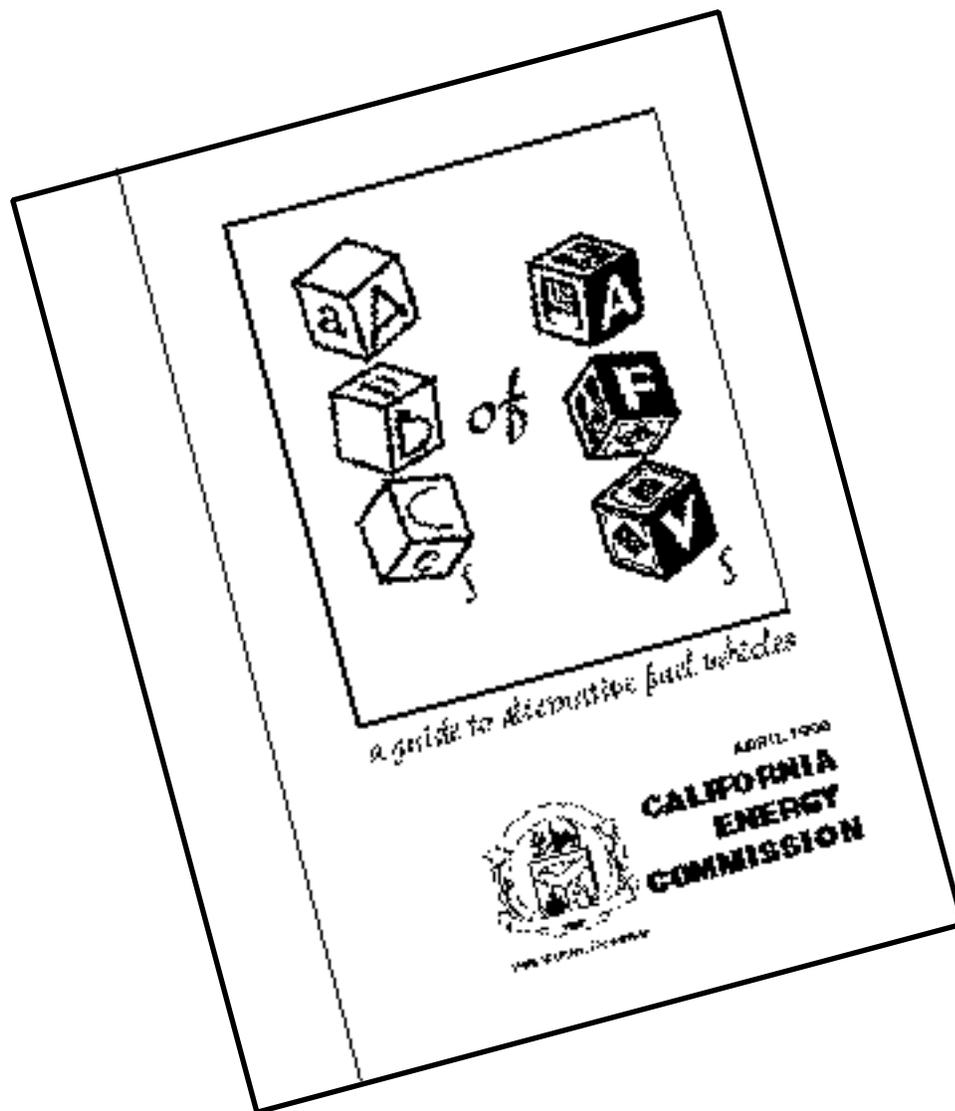
Pete Wilson, Governor

**Note About the Internet / PDF Version of the  
ABCs of AFVs...**

**Page numbers have been changed in this Adobe Acrobat Portable Document File (PDF) format edition from Roman numerals for cover and introductory pages to Arabic numerals. They, therefore, will not agree with page numbers on the Table of Contents page.**

**All other content remains the same.**

**We apologize for any inconvenience.**



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Bob Aldrich, *Principal Author*  
Claudia Chandler, *Assistant Director*

**MEDIA & PUBLIC COMMUNICATIONS OFFICE**

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**Bob Aldrich  
Information Officer  
California Energy Commission  
1516 Ninth Street, MS-29  
Sacramento, CA 95814**

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## **PUBLICATION INFORMATION**

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Includes Session Summary and list of attendees of California Alternative Fuel Vehicle Partnership (CAFVP) Symposium, and map and list of public EV recharging facilities in California.

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This edition updates many portions of the document and makes corrections to unintended minor errors in content. The Summary Session and list of attendees of the CAFVP Symposium have been deleted from this edition. This edition will be made available in its entirety on the Commission's Internet site as a downloadable Adobe Acrobat Portable Document Format (PDF) file.

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# Introduction

**T**he California Alternative Fuel Vehicle Partnership is a coalition of private companies; automobile makers; fuel providers; and federal, state and local government agencies that have banded together to support the introduction and commercialization of clean, alternative fuels and vehicles that use those fuels. The partnership is a means by which to share information with fleets and fleet managers who are required by law (or who desire) to purchase alternative fuel vehicles before the end of the decade. It is also a channel to inform and educate the general public and California drivers about the various clean, alternative fuels that are available today and in the future. The founding sponsors include:

- California Energy Commission (*partnership chair*)
- California Department of Transportation
- California Department of General Services, Office of Fleet Administration
- California Electric Transportation Coalition
- California Natural Gas Vehicle Coalition
- Regional Clean Air Coalitions
- Sacramento Metropolitan Air Quality Management District
- South Coast Air Quality Management District
- U.S. Department of Energy
- U.S. General Services Administration

**This report** was prepared by **California Energy Commission** Information Officer Bob Aldrich with input from various sponsoring members. The Commission is the state's primary energy policy and planning agency and has been involved in the testing and demonstrating of alternative transportation fuels since 1978. As part of the state's energy policy, the Commission supports the use of clean, alternative fuels to reduce our state's dependence on petroleum and to improve air quality.

The Energy Commission has been involved in all areas of transportation fuel research, development, demonstration and commercialization. It has worked with automobile and heavy-duty vehicle and engine manufacturers to advance the state-of-the-art of alternative fuel technology. By doing so, California continues its international leadership in alternative energy and helps create economic advantages for our state.

## Acknowledgements

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# Chapter 1

## An Overview of Alternative Fuel Vehicles

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### What Are Alternative Fuel Vehicles?

Alternative Fuel Vehicles (AFVs) are vehicles that run on fuels other than petroleum products. They have been with us in one form or another for more than one-hundred years. Only recently, however, have they become more commonplace.

According to the definition in federal law, alternative fuels include:

- Alcohol fuels such as methanol (methyl alcohol), denatured ethanol (ethyl alcohol) and other alcohols, in pure form (called “neat” alcohols) or in mixtures of 85 percent by volume (and mixed with up to 15 percent unleaded regular gasoline – M85 and E85) or more
- Compressed natural gas (CNG)
- Electricity
- Hydrogen
- Liquefied natural gas (LNG)
- Liquefied petroleum gas (LPG)
- Coal-derived liquid fuels
- Fuels other than alcohols derived from biological materials: like soy bean, rapeseed or other vegetable oil-based fuels

These fuels are described more completely in the chapters that follow.

Vehicles using these fuels can be either original equipment manufactured (OEM) vehicles made by auto companies or conversions.

Before the introduction of gasoline as a motor fuel in the late 1800s, vehicles were often powered by what are now considered alternative fuels. For example, illuminating or coal gas (a form of methane or natural gas) was used in early prototype internal combustion vehicles in the 1860s. Electricity, stored in lead acid batteries, was a popular energy source for vehicles from as early as the 1830s until the 1920s. In the 1880s, Henry Ford built one of his first automobiles and fueled

it on ethanol, which was often called “farm alcohol” because it was made from corn. His early Model Ts were designed with an adjustable carburetor to allow them to run on alcohol fuel. Liquefied petroleum gas (commonly called propane) has been used as a transportation fuel for more than 60 years.

In those early years of the horseless carriage, naturally formed gasoline was expensive and often sold by the pint in pharmacies; it was also used as a cleaning solvent. New petroleum refining technologies (thermal cracking and eventually catalytic cracking), however, produced gasoline inexpensively; and gasoline, because of its high energy content, became the fuel of choice for internal combustion engines.

Now many of these “alternatives” to gasoline are returning to the transportation fuel market, driven by state and federal government mandates for cleaner alternatives to gasoline and diesel. Alternative fuels are needed for two main reasons: energy security and air quality.

### Why AFVs Are Important

California’s transportation system is vital to the state’s economy, but our gasoline- and diesel-fueled cars, buses and trucks are also our greatest source of air pollution. As oil prices have dropped throughout the world, as the number of registered vehicles has increased and because we often live farther away from our work, Californians are driving more today than we did just five years ago. Couple the increased use of petroleum products, the sheer number of vehicles on the road and California’s geography and you have the perfect recipe for air pollution. California’s cities and countryside frequently blanketed by smog.

To attack California’s air quality problem and as a response to the oil crises of the 1970s, three Governors, the Legislature, the California Energy Commission, the Air Resources Board and other California public agencies assumed a national leadership role and committed to fuel diversity with cleaner, alternative fuels and a market for the vehicles that use those fuels.

Working with automakers, fuel producers and utility companies, air quality districts, and the private and public sector, California is making progress toward

California Vehicle Statistics						
	1989	1990	1991	1992	1993	1994
Total Registered Vehicles	22,367,821	22,678,552	22,957,474	22,793,908	22,982,288	22,843,141
Vehicle Miles of Travel (in millions of miles)	134,371	139,209	139,680	141,686	142,343	144,141
Taxable Gasoline Sales (millions of gallons, excluding aviation fuel)	13,206	13,377	13,161	13,064	13,202	13,262

achieving a truly diverse transportation landscape – one that will provide the consumer competitive choices in transportation technology, fuels and fueling options, while meeting California's increasingly stringent clean air goals.

These choices will include not only reformulated gasoline (a cleaner-burning gasoline that uses oxygenates to assist in more complete combustion) and clean diesel to fuel our transportation but also electric-, ethanol-, methanol-, natural gas- and propane-powered vehicles, each playing their own role in diversifying our transportation fuels.

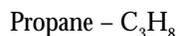
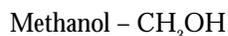
The use of alternative fuels for transportation can have a tremendously positive impact on California's economy. Using alternative fuels can help stop the outflow of jobs and dollars caused by buying oil produced outside of our state.

California produces only 45 percent of the oil it consumes. About 51 percent comes from Alaskan oil fields; the remaining four percent comes from foreign sources (mostly Indonesia). This will change as California's and Alaska's oil production decreases. The Energy Commission's *1993 Fuels Report* estimates that Alaska's oil production will decline six percent between 1992 and the year 2000. Production from 2000 to 2015 will decline more sharply, 15 percent per year. California's production is also expected to shrink. Foreign sources of crude oil will be relied upon more heavily in the future unless alternatives are found to replace this loss of domestically-produced fuel.

## Alternative Fuels Are Cleaner

Alternative fuels are inherently cleaner than gasoline because they are chemically less complex than gasoline, and when oxidized or burned, they burn "cleaner" with fewer emissions.

Consider the following chemical equations for various fuels:



(one of the **many** component molecules found in gasoline)

It can be seen just on this very simple level that these molecules are less complex. The longer and the more chemically complex a molecule is, the less likely it is to be completely burned. This incomplete combustion of the molecule in an internal combustion engine releases carbon monoxide, nitrogen oxide and other molecules in the exhaust. Alternative fuels,

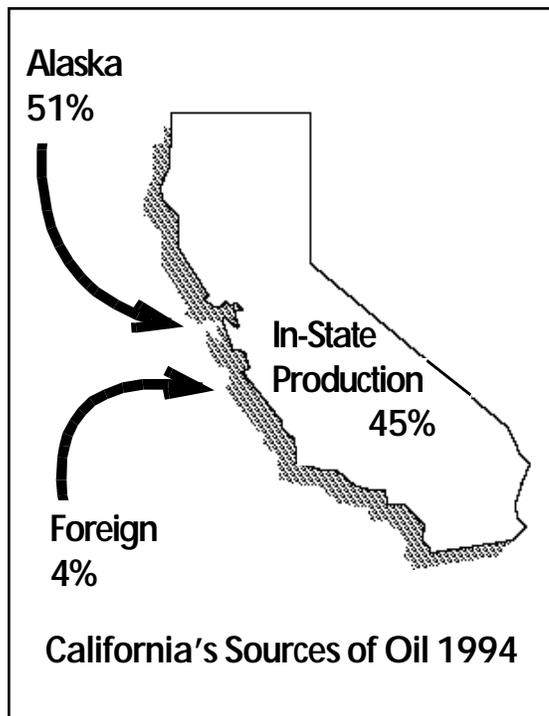
because of the simpler chemical make up, release fewer emissions from incomplete combustion. The fact that alternatives are cleaner can be proven by the actual use of the fuel in a motor vehicle and running emissions testing. In addition, alternative fuels evaporate less readily than gasoline does. This evaporation from a car's fuel tank also contributes to our smog.

It is important, however, to recognize that use of alternative fuels doesn't automatically yield emission benefits. With more stringent vehicle tailpipe emission standards, cleaner-burning gasoline, better emission controls on vehicles, etc., alternative fuels face an increasing challenge to demonstrate actual emission advantages over gasoline.

Electric vehicles, which have no internal combustion engine, offer an even better alternative because they do not burn a fuel. Their only sources of "pollution" are the power plants that create the electricity, which can also be regulated more closely for their sources of pollution. But electric have a trade off in range and longevity of their batteries that may be unacceptable to some consumers.

## Emission Characteristics of Alternative Fuels

From 1992 to 1994, one of the most comprehensive side-by-side studies of alternative fuels was conducted



by Battelle Memorial Institute on vehicles in Southern California. The CleanFleet Project, or the South Coast Alternative Fuels Demonstration Project, tested six fuels in 111 Federal Express delivery vans, which drove more than three million miles during the two-year study. The study used Chevrolet, Dodge and Ford vans that were similar in characteristics and in usage.

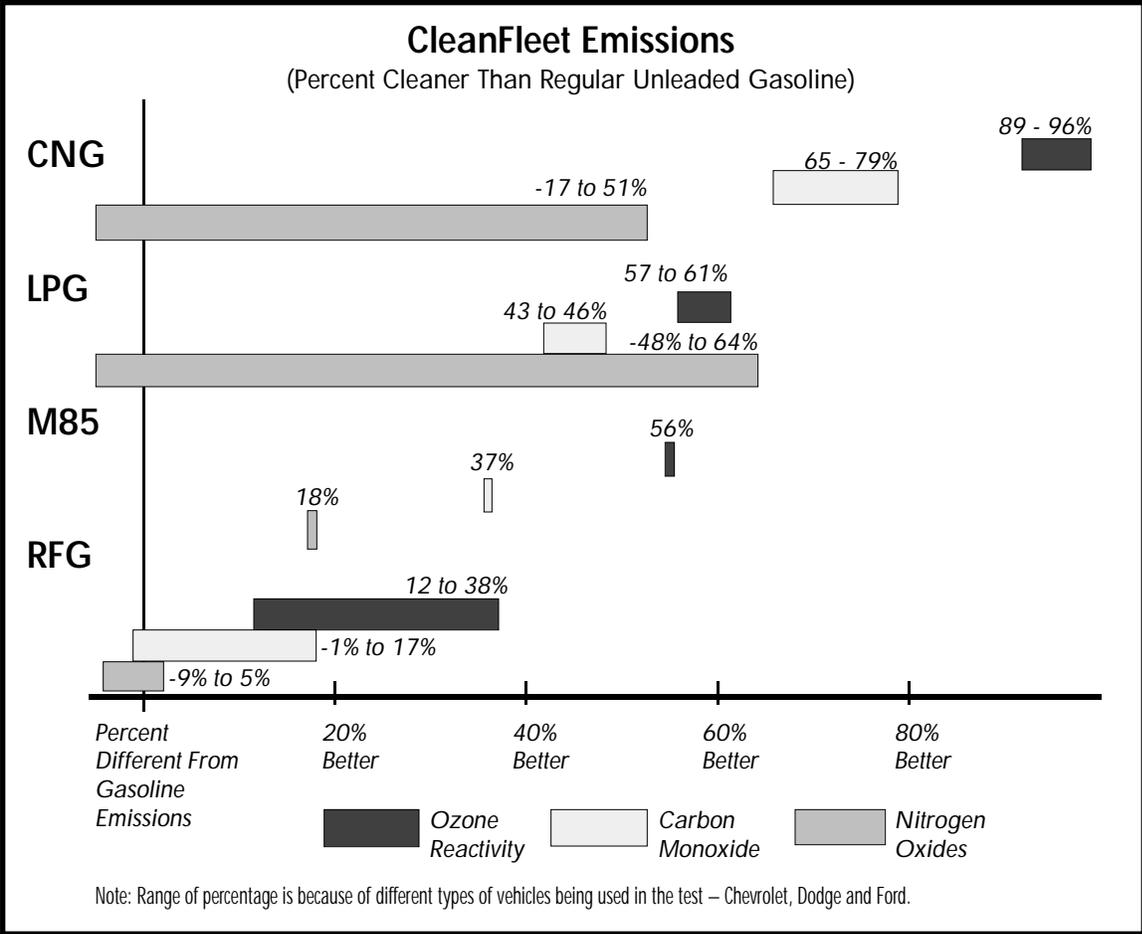
Emission results from the study indicate that all five of the fuels: compressed natural gas, electricity, methanol, propane and reformulated (ARB Phase 2) gasoline bested regular gasoline in nearly all emissions. (Ethanol was not used in this test because of its limited availability in California.) Vans fueled with regular unleaded gasoline were used as a control group by which the other fuels were compared.

The alternative fuels had less emissions than regular gasoline and were better than reformulated gasoline. Use of compressed natural gas showed carbon monoxide (CO) levels of 65 to 76 percent less than regular gasoline. Ozone reactivity for CNG was 89 to 96 percent cleaner than gasoline. Methanol vehicles had 37 percent less CO emissions than gasoline and up to 56 percent less ozone reactivity. Propane-powered vehicles had 43 to 46 percent less CO and 57 to 61 percent better ozone reactivity. Reformulated Phase 2 gasoline was also cleaner with 13 to 17 percent less CO on two types of vans (it was, however, one percent worse than regular unleaded gasoline on Ford vans). RFG's ozone reactivity was 12 to 38 percent cleaner than regular unleaded gasoline. The study also included two electric vehicles.

The CleanFleet Project used vehicles with the best technology for the time (1992 model year vehicles), and future emission results with newer technologies are expected to be even better as these technologies advance and mature.

## Energy Content of Alternative Fuels

Petroleum-based fuels (gasoline and diesel) offer excellent energy content by volume. By comparison, alternative fuels have less energy density. Hence, the fuels may have less mileage on a gallon to gallon basis than gasoline. On the next page is a chart that compares the energy density of the various fuels.



### Comparison of Fuel Energy Content

Fuel	Pressure	Btu/gal.	Ratio of Energy Content Compared to Gasoline*
Diesel		129,000	0.89 to 1
Gasoline		115,400	1.00 to 1
E85		105,545	1.09 to 1
Propane		84,000	1.40 to 1
Ethanol		75,000	1.54 to 1
LNG		73,500	1.57 to 1
M85		65,350	1.77 to 1
Methanol		56,500	2.04 to 1
CNG	@ 5845 psi	56,500	2.04 to 1
Liquid Hydrogen		34,000	3.39 to 1
CNG	@ 3000 psi	29,000	3.98 to 1
Hydrogen	@ 3000 psi	9,667	11.94 to 1

\* Note: These ratios do not reflect actual "in-use substitution ratios" due to engine inefficiencies. (For example, some early model FFVs using M85 had a ratio of 1.64 gallons of M85 to drive the same distance as one gallon of gasoline.)

## History of California's Involvement in Clean Alternative Fuel Vehicle Development

California has been at the forefront of developing clean, alternative fuels and vehicles. Since 1978, the state Energy Commission has worked with auto makers, fuel providers and utility companies, universities and research institutes, and research and development companies to advance the state-of-the art in alternative and efficient vehicles. In this endeavor, California has committed more than \$130 million toward alternative fuels and vehicles. Most of this money has come from fines paid by oil companies from settlement of lawsuits for over-charging consumers at the pumps during the oil crises of the 1970s. The programs the Commission has undertaken cover all aspects of vehicle and engine technologies.

**1978 California Begins Its AFVs Program** – Energy Commission begins its first alternative fuel vehicle demonstration program. Honda CVCCs used a gasoline blended with ethanol and methanol in side-by-side test program. Early national emphasis was on domestic coal-derived synthetic fuels: shale oil, gasoline, methanol, hydrogen. Goals were for alternative fuels to be able to displace oil and meet California emissions standards.

**1980** Ford Pintos were used to continue testing ethanol and methanol blends with gasoline.

**1981** Commission creates a methanol demonstration fleet with Ford Motor Company and put a limited number of test methanol-powered Ford Escorts in the County of Los Angeles fleet in 1981 and 1982. Volkswagen Rabbits, factory-built to run on ethanol and methanol were delivered in late 1981 to be added to the program.

**1983**

- Commission funds the first two transit buses in country to run on methanol. The buses, named Methanol 1 and Methanol 2, operated in commuter service between Marin County and City of San Francisco.
- 500 “dedicated” methanol-powered Ford Escorts put into state and local government fleets. Vehicles gained 20 million miles of on-road experience. The fuel showed a 50% to 80% emission reduction potential. A handful of these vehicles were still in service in various city and county fleets in the early 1990s.

**1986**

- Commission's Energy Technologies Advancement Program funds the retrofit of three diesel engines to methanol fuel in a \$1.8 million project. Engines used in Riverside Transit Agency buses.
- Commission begins its Heavy-Duty Truck Demonstration Program with \$700,000, augmented by additional funds later. This joint project was done with South Coast Air Quality Management District and five engine manufacturers: Caterpillar, Cummins, Detroit Diesel, Ford and Navistar. Vehicles placed at eight host sites included: water delivery truck, refuse haulers, dump trucks, sludge hauler, tractor/trailers and line truck.

**1987**

- Assembly Bill 234 directs the Energy Commission to study and report back to the Legislature on the cost and availability of low-emission fuels and vehicles.
- Ford announces Flexible Fuel Vehicle (FFV) technology – allows vehicles to run on methanol OR gasoline from a single tank. Ford produces Crown Victoria FFVs for demonstration fleet. A total of 217 Crown Victoria FFVs built between 1987 and 1989.

- Commission's ETAP project funds development of a hybrid electric vehicle. The \$404,000 project done with Electric Auto Association and Stanford University. It converted a Chevrolet Corsica to a hybrid EV with gasoline-powered generator.

1988

- Safe School Bus Program is created by Assembly Bill 35, authored by Assemblyman Richard Katz. The program provides \$100 million program in three phases to replace buses built prior to 1977 Federal Motor Vehicle Safety Standards. A minimum of 35% of vehicles must be powered by fuels other than petroleum-based. The three phases include:
  - Phase 1** – 14 school districts and consortia are involved; 163 buses purchased: 103 advanced diesel, 50 methanol, 10 compressed natural gas. Buses delivered in 1989.
  - Phase 2** – 47 school districts and consortia are involved; 400 buses purchased: 200 advanced diesel, 100 methanol, 100 compressed natural gas. Buses delivered by fall of 1993.
  - Phase 3** – 218 CNG, advanced diesel and electric school buses, built by Blue Bird Bus Company will be split among XXX school districts and transportation consortia. Delivery of the buses will begin in June 1996.
- GM announces its own Variable Fuel Vehicle (running on M85) and builds 20 Chevrolet Corsica Variable Fuel Vehicles for use in State of California and air district fleets in demonstration programs.
- 1988 Alternative Motor Fuels Act passes Congress. It establishes Corporate Average Fuel Economy credits for AFVs produced by auto companies.
- Energy Commission establishes California Fuel Methanol Reserve. ARCO signs agreement with Energy Commission to establish M85 fueling stations at a number of its gasoline stations. Other oil companies follow: Chevron, Exxon, Mobil, Shell, Texaco and Ultramar. Commission signs contracts for 83 M85 facilities in California for ten-year demonstration program. (First M85 station dedicated in June 1989 by then-Vice-President George Bush in Los Angeles.)
- Commission funds ETAP project to develop medium-duty natural gas engine for UPS step-van in a \$1.5 million project done with Acurex Corporation, Mountain View, Calif.

1989

- ARCO announces its first Reformulated Gasolines — EC1, EC Premium and eventually ECX. In 1990, ARCO says its ECX will be as clean as M85.
- Chevrolet delivers first of its Lumina Variable Fuel Vehicles to the Energy Commission. Eventually 265 of the Lumina VFVs are delivered to fleets in 1990. GM announces it will sell up to 2,000 Lumina VFVs in 1992.

1990

- Ford delivers 250 – 1991 Model Year Taurus Flexible Fuel Vehicles for demonstration in government/private fleets and produces 183 Econoline Van FFVs for 1992.
- Clean Air Act passed by Congress: Establishes California Pilot Program requiring 150,000 clean fuel vehicles a year for California by 1996, increasing to 300,000 a year by 1999. Vehicles can run on reformulated gasoline (one of the federally-designated “clean” fuels). Allows other states to adopt California's LEV emission standards.

- California Air Resources Board Low Emission Vehicle and Clean Fuel Availability Regulations adopted September 1990. Requires ZEVs to be offered for sale in 1998.

#### 1991

- Chrysler, with the Commission at its news conference, announces it will produce up to 2,500 Plymouth Acclaims and Dodge Spirits FFVs to run on methanol in 1992 Model Year. They offer the flexible fuel option at no extra cost above a gasoline vehicle. Other auto companies follow suit.
- Commission's Electric Vehicle Demonstration Program begun in partnership with Pacific Gas and Electric Company. The project will demonstrate three Conceptor G-Van EVs in a three-year program. Vans used by Cities of Oakland and Santa Rosa for mail delivery and in Yosemite National Park. Total of \$60,000 from Commission and \$60,000 from PG&E.
- Advanced Technology EV Demo Program announced by the Commission. Contract Opportunity Notice sent to 250 manufacturers of EVs, hybrids, developers and others, with responses received from 20 companies. Four companies chosen that met performance specifications, and a total of \$692,000 from Commission plus money from air districts and other governmental agencies was devoted to the projects. These included:
  - ☞ Chrysler TEVan - Four purchased with either Nickel-Cadmium or Nickel-Iron batteries
  - ☞ Ford Ecostar - Seven purchased with Sodium Sulfur batteries
  - ☞ Solectria Force - Four purchased with Advanced Lead-Acid
  - ☞ Volkswagen Jetta/Golf EV - VW decides later to withdraw

#### 1992

- Commission co-funds CALSTART. The consortium is made up of aerospace, auto, electronic and computer companies; universities and colleges; and government agencies — more than 80 members. A total of \$2 million was committed by the California Energy Commission to match \$4 million in federal support and more than \$20 million in private capital. The consortium's goal is to establish an advanced transportation technologies industry in California. CALSTART produces a Showcase EV (using components from California companies) for display at international auto shows and other projects.
- Light-Duty Natural Gas Vehicle Demonstration Program: Commission pays for half of differential cost of equipping 100 GMC and Chevrolet 1992 model year 3/4-ton dedicated natural gas pickup trucks. They were placed into service in ten fleets around the state (out of about 200 NGV trucks sold). The five-year demonstration program ended early, however, after all trucks were recalled in 1994 due to poor CNG cylinder design following two tank ruptures (San Francisco and Minnesota).
- Project with Vons Companies Inc. (California's largest supermarket company), Ford, National Renewable Energy Laboratory, SoCal Gas, SCAQMD places a heavy-duty natural gas-powered truck on the road. The project uses a Ford LTLA-9000 "Aeromax" tractor with Caterpillar G3406 engine. Pulled trailer between El Monte and Bakersfield over the "Grapevine" and the 4,183-foot T  jon Pass. It is the country's first long-haul CNG-fueled truck with an OEM engine.

#### 1993

- NGV Demonstration Program – Cost-sharing with utility companies to purchase equipment for 40 vehicles. Vehicles placed with: City of Ontario – five B-350 Dodge RAM Vans for rideshare program; County of Sacramento – five GMC Sierra pickup trucks for County Dept. of Public Works; and VPSI Commuter Vanpools – 30 Dodge B-350 RAM Vans for use in Orange County.

- Commission creates the Transportation Energy Technologies Advancement Program (TETAP) and funds research by California companies in a number of areas. Including:
  - ☞ \$66,666 toward medium-duty CNG engine for delivery vehicles with Aucurex Environmental in Mountainview, Calif.
  - ☞ SMUD Advanced Flywheel Project: \$4 million project with American Flywheel & Honeywell Systems.
  - ☞ CALSTART Electric School Bus: \$1 million project to retrofit two diesel buses to electricity and build one “ground-up” bus.
  - ☞ Hughes Electric Shuttle Bus: \$580,000 project to place an advanced 30-foot EV bus at LAX. The project was later withdrawn by Hughes.
  - ☞ GM Impact PrEView Program: \$500,000 from Energy Commission toward program that will “loan” GM Impacts to 1,000 drivers around U.S. for two to four weeks. Delivery of first group of Impacts was in Los Angeles, June 23, 1994. Cars will be tested in L.A., Sacramento, San Diego and San Francisco and eight other cities across country.
  - ☞ Cummins Engine: \$977,000 project to develop advanced turbocharger for a diesel engine.
- Commission Diesel Emission Reduction Fund Program begins using fine money collected from polluting heavy-duty vehicles. Projects funded in this first year include:
  - ☞ Cal State Fresno, \$19,672 – using water injection to clean diesel exhaust
  - ☞ Cummins Engine, \$480,000 project – development of low-cost particulate trap
- CE – CERT Advanced Transportation Research & Testing: Energy Commission gives \$1,400,000 toward University of California, Riverside’s College of Engineering – Center for Environmental Research and Technology (CE – CERT). CE-CERT is a \$125 million research center also funded by Energy Commission, technology reinvestment funds, U.S. Department of Energy, auto industry, etc. Its primary research areas include: atmospheric processes, vehicle emissions, environmental modeling, transportation systems, advanced vehicle engineering, renewable fuels, manufacturing processes and stationary source emissions.

1994

- Alternative Fuel Vehicle Demonstration Program in Yosemite National Park created by Senate Bill 314, authored by State Senator Dan McCorquodale. In cooperation with National Park Service, Caltrans, local transit companies and Pacific Gas and Electric Company, the Energy Commission awards \$640,000 for projects in the park:
  - ☞ Yosemite Electric Bus Program: Park’s concessionaire operates ten diesel powered buses in Yosemite Valley, carrying three million visitors a year. The program replaces diesel buses with electric buses. In 1995, three or four electric buses to be put into service in a three-year demonstration program. Total Cost: \$1.47 million (\$500,000 from Commission).
  - ☞ Yosemite Natural Gas Tourist & Transit Buses: VIA Adventures undertakes a \$350,000 project to convert up to four buses to compressed natural gas. These buses provide daily transit service from San Joaquin Valley and Amtrak connector service to Yosemite. California Yosemite Tours does a \$775,000 project to convert five transit buses to CNG for daily transit service from Fresno to Yosemite and Sequoia /Kings Canyon.
- Commission TETAP funds six more projects:
  - ☞ Amerigon – Advanced Heating/Cooling System for EVs - \$675,000 project.
  - ☞ APS Systems – Advanced EV Shuttle & Paratransit Buses - \$440,000 project.
  - ☞ CALSTART – Hybrid EV / Natural Gas, 40-foot Transit Bus - \$1.1 million project.
  - ☞ Pinnacle Research Institute – Ultra-Capacitor for EVs and Hybrids - \$690,000 project

- ☞ U.S. Electricar – Conversion to electricity of Grumman “Long Life” U.S. Postal Service Delivery Trucks - \$855,000 project with six Post Office EVs split between Torrance, California, and USPS Headquarters in Merrifield, Virginia.
  - ☞ Dyna-Cam - \$607,569 toward development of 210 hp Dyna-Cam Aero Engine to run on compressed natural gas. Project suspended in late 1994.
- Medium-Duty NGV Program - \$600,000 from Commission and \$174,000 from natural gas utilities (PG&E, SoCal Gas, SDG&E, Long Beach Gas) funds 54 natural gas vehicles in diverse range of uses: package delivery trucks, dump trucks, shuttle buses, “trolley” buses, tow truck, utility crew trucks. Ten public and private fleets participating, including: Cities of Chula Vista, Long Beach, Ontario and Whittier; Monterey County; Sacramento Metro Airport; United Parcel Service of Los Angeles; Dydee Diaper; Center City Towing in San Diego.
- 1994 demo project with The Los Angeles Times/Times Mirror Company, SCAQMD, SoCal Gas, National Renewable Energy Laboratory (NREL), American Trucking Association Foundation (ATAF) to demo a heavy-duty natural gas truck. The project uses a Ford LTLA-9000 “Aeromax” tractor using Detroit Diesel Corporation Series 60-G, 370 horsepower engine using CNG. The truck travels an interurban route between Orange County and downtown L.A.
- Project with Los Angeles County Sanitation District, SCAQMD, SoCal Gas, NREL and ATAF to demo a heavy-duty natural gas truck. The truck is a Freightliner tractor using Detroit Diesel Corporation Series 60-G 370 horsepower engine. The vehicle will be powered by Cleaned Landfill Gas (or CLG, which is mostly methane given off by decomposition at landfills).
- Diesel Emission Reduction Fund: two projects funded
  - ☞ CeraMem Corp., \$300,000 project – Exhaust Gas Recirculation and particulate filter
  - ☞ Southwest Research Institute, \$1 million project – Direct and indirect injection systems

**1995 For information about Commission programs in 1995, please contact the Commission’s Transportation Technology and Fuels Office at (916) 654-4634.**

1996

- March 29, 1996: California Air Resources Board modifies its Zero-Emission Vehicle mandates, scraping its 1990 regulation that required phase-in of ZEVs from 1998 to 2003. Instead, auto companies will voluntarily introduce ZEVs from 1998 to 2002. In model year 2003, 10 percent of all vehicles offered for sale by the major auto companies will have to be ZEVs.

**For information about Commission programs in 1996 and beyond, please contact the Commission’s Transportation Technology and Fuels Office at (916) 654-4634.**

## Deciding Which Fuels Are Best For You or Your Fleet

When determining what type(s) of fuels to use, private vehicle owners and fleet managers should weigh all the factors: economics; which models are available; rebates and incentives offered by auto companies, government and utilities; ease of refueling; whether you'll install a fueling facility on your own property; whether to have a dedicated vehicle or a bi-fuel vehicle; distances cars will need to travel; trade-in value; maintenance; etc. One fuel might be perfect for one application, but that same fuel might not be good for another.

This booklet will help you with the basic information on each of the different fuels. If you need additional general help in determining what kind of alternative fuel vehicle you should purchase please contact the following. There are listings at the end of each chapter for specific contacts on various fuels.

### General Information

#### **California Energy Commission**

Transportation Technology & Fuels Office  
1516 Ninth Street, MS-41  
Sacramento, CA 95814  
(916) 654-4634

### Compressed Natural Gas

#### **California NGV Coalition**

925 L Street, Suite 1485  
Sacramento, CA 95814  
(916) 448-5036

### Electric Vehicles

#### **California Electric Transportation Coalition**

925 L Street, Suite 1490  
Sacramento, CA 95814  
(916) 552-7070

### Ethanol-Powered Vehicles

#### **California Renewable Fuels Council**

3304 Yorba Linda Blvd., Suite 249  
Fullerton, CA 92631  
(714) 996-6540

### Propane-Powered Vehicles

#### **Propane Vehicle Council**

2102 Business Center Drive, Suite 130  
Irvine, CA 92714  
(714) 253-5757

### General Information

#### **National Alternative Fuels Hotline**

P.O. Box 12316  
Arlington, VA 22209  
(800) 423-1DOE (1363)

# Chapter 2

## Laws, Regulations and Requirements Affecting Alternative Fuel Vehicles

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There are three main laws and regulations that relate to alternative fuels and the vehicles that use those fuels: the federal 1990 Clean Air Act Amendments, the 1992 National Energy Policy Act, and the 1990 California Air Resources Board's Low Emission Vehicle Requirements (amended in March 1996). Additional regulations that may affect businesses and fleets have been approved at state and local levels by the Legislature, various air quality districts and the Governor Pete Wilson's Executive Order of 1994. This chapter will look at the policies and also at incentives offered for Alternative Fuel Vehicles.

### Federal Laws

The **Clean Air Act Amendments (CAAA) of 1990** (Public Law 101-549) was passed by Congress to amend the original Clean Air Act passed 20 years earlier. The Amendments include provisions that require gasoline refiners to reformulate their gasolines to meet more stringent emission standards. In cities that do not meet federal air quality requirements set forth in the 1990 Amendments, gasolines must be reformulated during certain months, when carbon monoxide and ozone pollution are most serious. The regulations also require certain fleet operators to use clean fuel vehicles in 22 metropolitan areas nationwide. The clean fuels included reformulated gasoline and many alternative fuels.

The CAAA also established the California Pilot Program requiring 150,000 clean fuel vehicles a year for California by 1996, increasing to 300,000 a year by 1999. Vehicles can use reformulated gasoline (one of the federally-designated "clean" fuels). **The law allowed other states to adopt California's Low Emission Vehicle standards.**

Prior to the CAAA, Congress passed the Alternative Motor Fuels Act of 1988 – AMFA (Public Law 100-494), which encouraged the development, production and demonstration of alternative motor fuels and alternative fuel vehicles. That law, however, did not affect fleets. It did establish Corporate Average Fuel Economy (CAFE) credits for auto companies producing AFVs.

The **National Energy Policy Act of 1992 (EPAct)** is Public Law 102-486. The broad-ranging act was signed into law by President Bush on October 24, 1992. Several titles deal with alternative transportation fuels. For alternative transportation fuels, EPAct:

- Accelerates the purchase requirements for alternative fuel vehicles by the federal fleet. The numbers were increased further by Executive Order 12844 signed by President Clinton (see footnotes on page 16).
- Proposes a cap on credits that auto manufacturers can earn by producing dual-fuel and flexible fuel vehicles
- Requires fleets in large urban areas to purchase not only clean fuel vehicles but vehicles that use alternative fuels

EPAct also establishes tax incentives for purchase of alternative fuel vehicles and conversion of conventional gasoline vehicles to alternative fuels by the private sector. The chart on the following pages gives a comparison between the major provisions of the two federal laws.

### California Regulations

California's geography, climate and number of vehicles create California's unique smog problems. Major urban areas of the state are surrounded by mountains that trap pollution in stagnant air. Persistent stagnant weather conditions during much of the year not only prevent pollution from dispersing in the atmosphere, but also increase the amount of time pollutant gases are exposed to sunlight, which prompts the chemical reactions that create smog.

In September 1988, Governor George Deukmejian signed the California Clean Air Act, Assembly Bill 2595, authored by Assemblyman Byron Sher. The Act defined a framework for air quality planning and regulations, establishing a new means for reaching California's air quality goals.

*(Text continues on page 17.)*

Provision	Clean Air Act Amendments of 1990	National Energy Policy Act of 1992
<b>Persons Affected</b>	Public or private fleet owners or operators with 10 or more vehicles capable of being centrally fueled. <b>Note: California fleets are exempt.</b>	"Persons" who own, operate, lease or control at least 50 vehicles in the U.S. (centrally fueled or capable of being centrally fueled), primarily operated in a Consolidated Metropolitan Statistical Area (CMSA) with a 1980 population of 250,000 or more.
<b>Areas Affected</b>	22 metropolitan areas with a 1980 populations of 250,000 or more and designated by the U.S. EPA as in severe or extreme non-attainment of either ambient ozone or carbon monoxide standards (See List A below).  Other areas may "opt-in" to the program per state air quality attainment strategy (no others areas have done so through mid-1994).	More than 120 cities with a 1980 population of 250,000 or more (See List B below for California cities.)
<b>Fleet Definition</b>	10 or more light-duty or heavy-duty vehicles located in the affected area.	Fleets of 20 or more light-duty vehicles, less than 8,500 pounds gross vehicle weight capable of being centrally fueled that are owned, operated, leased or controlled by a government entity or by another person who controls 50 or more such vehicles.
<b>Effective Dates</b>	Begins in 1998 (See List C below.)	1993 (federal fleets) 1997 (state fleets) 1997 ("fuel providers") 1999 (municipal/private) 2002 (municipal/private by DOE rule) (See List C below.)
<b>Purchase Requirements</b>	Clean Fuel Vehicle (CFV) Fleet Program (See List C below).	There are requirements for federal, state, fuel providers, municipal and private fleets. (See List C below.)
<b>Fuel Definition</b>	Clean Fuels including: • Methanol (M85) • Ethanol (E85) • Other alcohols • Reformulated gasoline • Clean Diesel • Natural gas • Liquefied petroleum gas (LPG)	Alternative Fuels including: • Methanol • Ethanol • Other alcohols, separately or in mixtures of 85% by volume or more (but not less than 70% volume by rule) with gasoline or other fuels • Compressed natural gas (CNG) • LPG • Hydrogen • "Coal-derived liquid fuels" • Fuels derived from "biological materials"

Provision	Clean Air Act Amendments of 1990	National Energy Policy Act of 1992
<b>Fuel Definition</b> (continued)	<ul style="list-style-type: none"> <li>• Electricity</li> <li>• “Any other power source” able to meet California vehicle emissions standards.</li> </ul>	<ul style="list-style-type: none"> <li>• Electricity</li> <li>• Any other fuel “substantially not petroleum” yielding “substantial energy security benefits and substantial environmental benefits.”</li> </ul> <b>Reformulated gasoline may not be used to meet EPA requirements.</b>
<b>Credits</b>	<p>Provides credits for CFV fleets. (California fleets are not covered.) Emissions reduction credits available for CFVs that are exempt from requirements, purchased in advance or requirement, or purchased in excess of minimum requirement.</p> <p>Credits can be transferred, “banked” or used to offset new sources within the same non-attainment area.</p>	<p>Credits earned if AFVs are acquired in excess of minimum required or in advance of date of requirement at the rate of one credit per vehicle.</p> <p>Credits earned are transferable from one area to another.</p>
<b>Buses</b>	<p><b>Bus Requirements</b> All buses initially in cities with populations of 750,000 or more would be operated on “clean fuels” (phased-in starting in 1994).</p> <p>Urban bus retrofit regulations are effective beginning in 1995. They will require buses to be retrofitted according to a schedule and meet stricter emissions standards, including a minimum reduction in particulates of 25%, either on a per-vehicle or fleet average basis.</p> <p><b>Bus Retrofit Requirements</b> Effective in 1995, new emissions requirements for rebuilt, heavy-duty diesel-engine urban buses will be applicable to model year 1993 or earlier.</p> <p>There is a 0.10 gram/bhp-hr (maximum) particulate mater (PM) emissions limit in cities with a population of 750,000 or more.</p>	<p><b>Bus Demonstrations</b> <b>Urban Buses:</b> The Department of Transportation (DOT) and Department of Energy (DOE) shall initiate cooperative ventures with local governments with populations of 100,000 or more to demonstrate the feasibility of commercializing the use of alternative fuels.</p> <p><b>School Buses:</b> DOT may provide financial assistance to local units of government (in urban areas with populations of 100,000 or more) to cover the incremental costs of operating and purchasing buses using alternative fuels, including vehicle conversions.</p>
<b>Off-Road Engines</b>	<p>US EPA is preparing to propose regulations to control emissions (NOx and PM) from heavy-duty (and other) engines used in off-road applications, including farm equipment, marine engines and locomotives.</p>	<p>US DOE is required to “conduct a study” to determine the effectiveness of using alternative fuels in off-road vehicles in “surface transportation” such as rail, airport vehicles, marine engines and others.</p>

Provision	Clean Air Act Amendments of 1990	National Energy Policy Act of 1992
<p><b>Tax Incentives</b></p>	<p>No provisions.</p>	<p>Maximum tax deductions are provided as follows for the incremental costs of AFVs (including retrofits) and refueling facilities placed in service after June 30, 1993:</p> <p>AFVs up to 10,000 lb. gvwt: <b>up to \$2,000</b></p> <p>AFVs 10,001 - 26,000 lb. gvwt: <b>up to \$5,000</b></p> <p>Trucks/Vans (over 26,000 lb gvwt): <b>\$50,000</b></p> <p>Buses with seating capacity of 20 or more adults: <b>\$50,000</b></p> <p>Electric Vehicles: <b>10% tax credit up to \$4,000/vehicle</b></p> <p>AFV Refueling Facility: <b>\$100,000</b></p>
<p><b>Biodiesel Study</b></p>	<p>Study on "alcohol esters of rapeseed oil" concerning its "feasibility, engine performance, emissions and production capability."</p>	<p>No provisions.</p>
<p><b>"Replacement Fuels"</b></p>	<p>No provisions.</p>	<p>The portion of a motor fuel that is methanol, ethanol, or other alcohol, CNG, LPG, hydrogen, coal-derived liquid fuel, fuel "other than alcohol" derived from "biological materials," electricity, and ethers.</p> <p>U.S. DOE may determine by rule that any other fuel that is "substantially not petroleum" and yielding "substantial energy security benefits and substantial environmental benefits" will qualify as a replacement fuel.</p> <p><b>National Petroleum Reduction Targets:</b></p> <p>By 2000: 10% replacement By 2010: 30% replacement</p>

**List A**  
**Areas Covered in Clean Air Act Amendments of 1990**  
(Clean-Fuel Vehicle Fleet Program)  
**California Cities/Regions in Bold**

Los Angeles-Anaheim-Riverside, CA  
Sacramento, CA  
**San Diego, CA**  
San Joaquin Valley, CA  
Southeast Desert, CA  
**Ventura County, CA**

Atlanta, GA  
Baltimore, MD  
Baton Rouge, LA  
Beaumont-Port Arthur, TX  
Chicago-Gary-Lake County, IL-IN-WI  
Denver-Boulder, CO  
El Paso, TX  
Greater Connecticut, CT  
Houston-Galveston-Brazoria, TX  
Milwaukee-Racine, WI  
New York-Long Island-Northern Jersey, NY-NJ  
Philadelphia-Wilmington-Trenton, PA-DE-MD-NJ  
Providence-Pawtucket-Fall River, RI-MA  
Springfield, MA  
Washington, DC Area, MD-VA-DC

**List B**  
**EPAct – Affected Areas in California**  
Metropolitan Areas of California with a  
1980 Population of 250,000 or More

Bakersfield	Fresno
Los Angeles-Anaheim-Riverside	Modesto
Sacramento	Salinas-Seaside-Monterey
San Diego	San Francisco-Oakland-San José
Santa Barbara-Santa Maria-Lompoc	Stockton

**List C**  
**Comparison of New AFV Purchase Requirements**  
**For Affected Vehicle Fleets**

Year	Clean Air Act	National Energy Policy Act of 1992 <sup>1)</sup>				
	(% of CFVs) Percentages Do Not Apply to California Fleets	Federal (% or # of AFVs)	State (% of AFVs)	Fuel Provider (% of AFVs)	Municipal & Private <sup>1)</sup> Early Rule (% of AFVs)	Municipal & Private <sup>1)</sup> Late Rule (% of AFVs)
1993		5000/7,500 <sup>2)</sup>				
1994		7500/11,250 <sup>2)</sup>				
1995		10000/15,000 <sup>2)</sup>				
1996		25%/17,500 <sup>2)</sup>	10%/25% <sup>3) 4)</sup>	30% <sup>4)</sup>		
1997		33%/20,000 <sup>2)</sup>	15%/33% <sup>3) 4)</sup>	50% <sup>4)</sup>		
1998	30%	50%/30,000 <sup>2)</sup>	25%/50% <sup>3) 4)</sup>	70% <sup>4)</sup>		
1999	50%	75%/40,000 <sup>2)</sup>	50%/75% <sup>3) 4)</sup>	90% <sup>4)</sup>	20%	
2000	70%	75%	75% <sup>3) 4)</sup>	90%	20%	
2001	100%	75%	75%	90%	20%	
2002	100%	75%	75%	90%	30%	20%
2003	100%	75%	75%	90%	40%	40%
2004	100%	75%	75%	90%	50%	60%
2005	100%	75%	75%	90%	60%	70%
2006	100%	75%	75%	90%	70%	70%

1) Under the National Energy Policy Act, the U.S. Secretary of Energy has two opportunities to rule on AFV purchases for private fleets. If a rulemaking is issued by December 16, 1996, then the percentages in the "early rule" column apply. If a rulemaking is not issued until later (January 1, 2000, deadline), then the percentages in the "late rule" column apply.

2) Federal fleet purchases were changed by Executive Order 12844 signed by President Bill Clinton in February 1993. This increases federal purchases (if vehicles are available from auto companies) to 7,500 in 1993; 11,250 in 1994; 15,000 in 1995; 17,500 in 1996; 20,000 in 1997; 30,000 in 1998; and 40,000 in 1999. Purchase percentages are based on about 50,000 vehicle acquisitions per year and vehicle turn-over/replacement after five years.

3) Percentage of AFVs required by State of California were increased by Executive Order No. W-100-94, signed by Governor Pete Wilson on August 15, 1994. The Executive Order requires: 25% of vehicles purchased in 1996 be AFVs; 33% be AFVs in 1997; 50% be AFVs in 1998; and 75% be AFVs in 1999 (if vehicles are available from manufacturer and at a reasonable cost). The order also requires that 10 percent, inclusive, must be Ultra-Low Emission Vehicles or Zero-Emission Vehicles in 1996 and beyond.

*(Note: Both the Presidential and Governor's Executive Orders are not fully binding in that vehicle acquisitions may be based on cost and availability of AFVs, availability of funds, etc.)*

4) In March 1996, The U.S. Department of Energy ruled that state and fuel providers will have an additional year to begin purchasing AFVs, thus delaying implementation for these two groups until 1997.

Under the act, the California Air Resources Board (ARB) set new car standards of 0.4 grams/mile of Nitrogen Oxides (NOx) for passenger vehicles beginning with the 1989 model year. In 1993, the standards became more stringent, requiring manufacturers to meet a 0.25 gram/mile standard for hydrocarbons and 3.4 grams/mile for carbon monoxide for all passenger vehicles and light-duty trucks (see chart).

Because of the enormity of its air pollution problems, California was allowed under the federal Clean Air Act Amendments of 1990 to continue to set its own standards for vehicle emissions. The law also allowed other states to use either the national standards, or they could opt for California's stricter standards; they could not create a third set of standards. Two states (New York and Massachusetts) have already done so, with Zero Emission Vehicle requirements going into effect in 1999, and 10 other states plus the District of Columbia (the Northeast Ozone Transport Committee) were awaiting approval (as of this writing) from the U.S. EPA to follow California's lead.

In September 1990, regulators at ARB adopted vehicle and fuels requirements, as well as a "reactivity protocol" for various clean fuels. It also took the unprecedented step of requiring a phase-in of even stricter emissions standards in California, including the first-ever provision for Zero Emission Vehicles (ZEVs). The Board set four levels of low-emission vehicles: Transitional Low Emission Vehicles, Low Emission Vehicles, Ultra-Low Emission Vehicles and Zero Emission Vehicles. The percentages of progressively cleaner vehicles were to be increased and phased-in over a ten-year period. The emissions levels could be reached by changes in fuel (either to reformulated or alternative – the regulation was fuel neutral) or in the

vehicle itself (such as better catalytic converters).

ARB's Low Emission Vehicle Regulations subjected all auto manufacturers to the more stringent LEV standard. Small-volume manufacturers (those selling less than 3,000 vehicles a year) are subject to a delayed timetable until the year 2000 to meet the LEV standards. For the ZEV mandate, those that sell 35,000 or more cars a year in California (Chrysler, Ford, General Motors, Honda, Mazda, Nissan and Toyota), were required to offer ZEVs for sale in 1998. Those selling less than 35,000 vehicles had until 2003 to comply; and those selling less than 3,000 vehicles were exempt. The only vehicles that currently qualify as ZEVs are electric vehicles.

The regulation was upheld by ARB in May 1994, when the Board reaffirmed its time table for implementation and noted that technical advances were on track.

In December 1995, however, ARB Chairman John Dunlop III directed agency staff to draft a new proposal to change the timetable for ZEVs. On March 28, 1996, the board members adopted this new timetable.

ARB essentially scraped the phase-in requirements from the 1998 model year through the year 2003. Instead, auto companies could voluntarily sell their Zero Emission Vehicles. Beginning in 2003, however, the mandate that 10 percent of vehicles must be ZEVs still stands.

In August 1994, Governor Pete Wilson issued an Executive Order to increase the number of AFVs purchased for California's state fleet use. The order increased the percentage of vehicles as much as 25 percent more than what the National Energy Policy Act required. (See footnote on previous page.)

In addition to the ARB regulations, various state laws have been passed that focus on clean, alternative fuels and AFVs.

### ARB Low Emission Standards for Passenger Cars & Light-Duty Vehicle

Emissions for 50,000 and 100,000 miles in Grams Per Mile

	NMOG		CO		NOx	
	50,000	100,000	50,000	100,000	50,000	100,000
1993 Standards	0.25	0.31	3.4	4.2	0.4	0.6
TLEV	0.125	0.156	3.4	4.2	0.4	0.6
LEV	0.075	0.90	3.4	4.2	0.2	0.3
ULEV	0.040	0.055	1.7	2.1	0.2	0.3
ZEV	zero		zero		zero	

Note: NMOG = Non-Methane Organic Gases, CO = Carbon Monoxide, NOx = Nitrogen Oxides; TLEV = Transitional Low Emission Vehicle, LEV = Low Emission Vehicle, ULEV = Ultra-Low Emission Vehicle, ZEV = Zero (tailpipe) Emission Vehicle. Emissions in grams per mile are allowed to increase as the car ages from 50,000-100,000 miles.

**California Air Resources Board Low Emission Vehicle  
Fleet Average Goals**

<i>Model Year</i>	<i>Conventional Standard</i>	<i>TLEV</i>	<i>LEV</i>	<i>ULEV</i>	<i>Original ZEV Mandate - 9/90</i>	<i>New ZEV Mandate - 3/96</i>
1993	40%					
1994	80%	10%				
1995	85%	15%				
1996	80%	20%				
1997	73%		25%	2%		
1998	48%		48%	2%	2%	<i>voluntary</i>
1999	23%		73%	2%	2%	<i>voluntary</i>
2000			96%	2%	2%	<i>voluntary</i>
2001			90%	5%	5%	<i>voluntary</i>
2002			85%	10%	5%	<i>voluntary</i>
2003			75%	15%	10%	10%

Note: **Only the ZEV percentages are mandated.** The others are potential percentages that the auto companies can use as goals. The auto companies must reach an across-the-fleet average for emissions.

Some of the more recent bills from both the state Senate (Senate Bill – SB) and Assembly (Assembly Bill – AB) are listed below. The bill number is followed by the author’s last name and its enrollment citation.

- **AB 234** (Leonard, Chapter 1326, Statutes of 1987) Defines Low Emission Vehicle, requires that the California Energy Commission study the cost and availability of low emission fuels and vehicles. Report issued in 1989 and updated in 1991 titled: *AB 234 Report – Cost & Availability of Low-Emission Motor Vehicles and Fuels*, Energy Commission publication number P500-91-009.
- **SB 1123** (Leonard, Chapter 796, Statutes of 1989) Amends the definition of LEV; requires state fleet purchases of AFVs if vehicles and funds are available.
- **SB 1006** (Leonard, Chapter 990, Statutes of 1989) Exempts the “incremental cost” of LEVs from the state sales tax. (Expired December 31, 1994. See incentives below.)
- **SB 2600** (Vuich, Chapter 1611, Statutes of 1990) Allows a state income tax credit for LEV purchases and conversions (amended by Senate Bill 146 in 1993). (See incentives below.)
- **AB 434** (Sher and Cortese, Chapter 807, Statutes of 1991) Allows Bay Area Air Quality Management Districts to collect a surcharge (up to four dollars) through local vehicle registrations to pay for air quality improvement programs in their district and to reduce air pollution from motor vehicles. These fees have been used to help fund various local district incentive programs for alternative fuel vehicles, ridesharing and fleet/employee trip-reduction programs, clean fuel buses, feeder buses/shuttle service, and other projects.
- **SB 135** (Boatwright, Chapter 496, Statutes of 1991) Effective January 1, 1997, requires public vehicles operated for compensation — transit vehicles and taxis — in districts not achieving air quality standards to meet ARB’s low emission standards
- **SB 1214** (Killea, Chapter 900, Statutes of 1991) Requires the California Energy Commission to forecast transportation energy demand. Staff report issued in February 1994 titled: *1993-1994 California Transportation Energy Analysis Report*, Energy Commission publication

number P300-94-002, Docket No. 92-TFER-1.

- **AB 3052** (Polanco, Chapter 762, Statutes of 1992) Requires the California Energy Commission to develop an infrastructure master plan for alternative transportation fuels – the CalFuels Plan. Report issued in September 1994 titled: *CalFuels Plan – Developing an Infrastructure Plan for Alternative Fuel Vehicles*. Energy Commission publication number P500-94-002.
- **AB 35** (Klehs, Chapter 873, Statutes of 1993) Conforms the state income tax credit for low emission vehicles to reflect the allowable federal tax credit for electric vehicles in the National Energy Policy Act.
- **SB 146** (Lewis, Chapter 875, Statutes of 1993) Expands the LEV tax credit to non-recreational off-road vehicles; extends the sunset on state low emission vehicle tax credit from January 1, 1995, to January 1, 1996; and deletes the sunset on the Use Fuel Tax Law provisions that sets the fuel tax rate for methanol and ethanol at one-half the rate for gasoline and diesel fuels.
- **SB 316** (Rosenthal, Chapter 956, Statutes of 1993) Existing law allows the South Coast Air Quality Management District to impose a vehicle registration surcharge to fund clean fuel and alternative fuel vehicle programs. SB 316 extends the sunset on the surcharge to August 1, 1999, and eliminates the sunset on the program.

## Local Air District Regulations

Local air quality districts can pass and enforce local air quality ordinances or regulations that will affect fleets, businesses and individuals. A number of districts have passed regulations affecting fleets. Below is a summation of the various regulations and incentives that are currently in force in four of the state's urban areas. Fleet managers are advised to contact their local air quality district for additional information. Those who do not live in a multi-county district shown on the map, should contact your local county's air

pollution control officer — the number should be listed in the government listings of your phone book.

## Bay Area Air Quality Management District (BAAQMD)

The BAAQMD requires large companies to develop a trip-reduction program or an Alternative Emission Reduction Program (AERP), which is updated every two years. The AERP can include clean fuel vehicles in employer fleets (either new or retrofit) or clean fuel buses (transit buses, school buses or shuttles). The employer must demonstrate, however, that the clean fuel vehicles are not being used by the vehicle manufacturer to fulfill the state LEV/ZEV requirements or by the employer to comply with any clean fuel vehicle fleet rule (such as under the National Energy Policy Act).

Public agencies and their fleets can request funding for clean fuel buses and demonstration projects using alternative fuel vehicles through the AB 434 Transportation Fund for Clean Air. This program applies only to public agencies including, but not limited to cities, counties, school districts, transit districts, and regional and state agencies. The BAAQMD places a high priority on projects funded through AB 434. About \$17 million is generated annually from the surcharge and used toward these programs.

## Sacramento Metropolitan Air Quality Management District (SMAQMD)

The SMAQMD has a rule that affects fleets with 15 or more vehicles in the district. Fleets are required to reduce emissions when they add or replace vehicles, when they replace a vehicle's engine, or when they rebuild an engine. It is up to the fleets to determine how they will reduce the vehicle's emissions — the rule is "fuel neutral" and is based on tailpipe emissions not on use of alternative fuels.

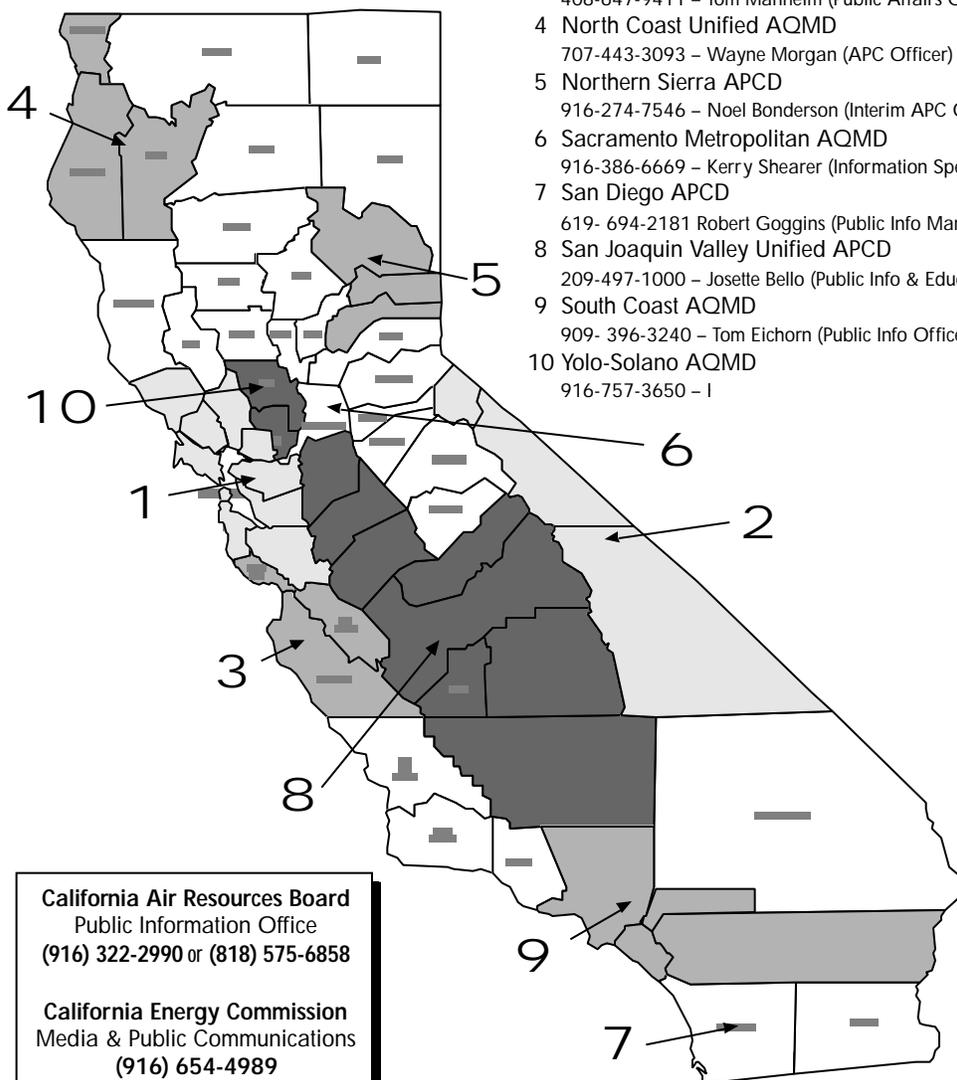
Fleets that purchase low emission vehicles can get credits for LEVs that are purchased above their required number. Fleets purchasing alternatively-fueled vehicles can get additional credits above the LEV credits. These credits can then be traded with other businesses in the district or to fleets considered by the district to be "under-achievers."

SMAQMD currently has a number of incentive programs in place or planned for the near future. These include:

# Multi-County and Major Air Quality Management and Air Pollution Control Districts in California

## Public Information Contacts

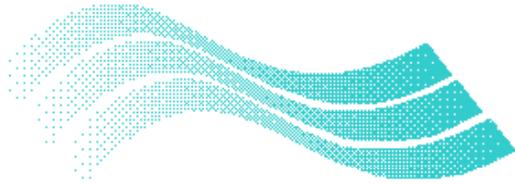
- 1 Bay Area AQMD  
415-771-6000 – Terry Lee (Dir. of Public Information)
- 2 Great Basin APCD  
619-872-8211 – Ellen Hardebeck (APC Officer)
- 3 Monterey Bay Unified APCD  
408-647-9411 – Tom Manheim (Public Affairs Officer)
- 4 North Coast Unified AQMD  
707-443-3093 – Wayne Morgan (APC Officer)
- 5 Northern Sierra APCD  
916-274-7546 – Noel Bonderson (Interim APC Officer)
- 6 Sacramento Metropolitan AQMD  
916-386-6669 – Kerry Shearer (Information Specialist)
- 7 San Diego APCD  
619- 694-2181 Robert Goggins (Public Info Manager)
- 8 San Joaquin Valley Unified APCD  
209-497-1000 – Josette Bello (Public Info & Education Officer)
- 9 South Coast AQMD  
909- 396-3240 – Tom Eichorn (Public Info Officer)
- 10 Yolo-Solano AQMD  
916-757-3650 – I



**California Air Resources Board**  
Public Information Office  
(916) 322-2990 or (818) 575-6858

**California Energy Commission**  
Media & Public Communications  
(916) 654-4989

## SACRAMENTO METROPOLITAN



# AIR QUALITY MANAGEMENT DISTRICT

1. Methanol fuel incentive — The SMAQMD provides \$200 of M85 to purchasers of Flexible Fuel Vehicles (FFVs). The FFV purchaser must either live in Sacramento County or operate the vehicle in Sacramento County at least 75 percent of the time in order to qualify. The fuel is provided through public access fueling network by issuing a \$200 credit to the purchaser's account with Chevron, which manages the retail fuel network billing system.
2. The SMAQMD has developed a cost-sharing matrix that would provide incentives for light- and medium-duty vehicles based on their air quality benefits.
3. The SMAQMD has a continuous filing policy for unique and/or innovative alternative fuel projects. These projects are reviewed by the District as they are received. There is no formal application other than to contact the SMAQMD with proposals.

### South Coast Air Quality Management District (SCAQMD)

Rule 1501, adopted by the SCAQMD in 1987 to encourage carpooling, use of public transit and other forms of ridesharing as a means to reduce auto emissions, has been replaced with Rule 1612 provides a menu of options for fleets. Contact SCAQMD for more details.

In 1995, the district surprised many by announcing a \$5,000 electric vehicle incentive on up to 1,200 EVs sold between 1996 and 1998. The rebates go directly to EV manufacturers and are effective July 1, 1996.

Finally, according to the SCAQMD, all basin fleets may be required under the U.S. Environmental Protection Agency's Federal Implementation Plan (FIP) to purchase many more alternative fuel vehicles than are required under the National Energy Policy Act. The FIP would be put into place if the EPA does not agree with the way California and its air districts have drafted their own clean air plans, called the State Implementation Plan or SIP.

Under the FIP, 50 percent of the basin fleets' new car purchases would have to be Inherently Low Emission Vehicles (ILEVs) in 1999. That increases to 70 percent ILEVs in the year 2000 and beyond. ILEVs are vehicles that are certified by the federal government to meet the California Air Resources Board's Low Emission Vehicle standards for non-methane organic gases and carbon monoxide and ULEV standards for Nitrogen oxides and do not emit any evaporative emissions.

### San Diego County Air Pollution Control District (APCD)

On November 29, 1994, the San Diego County Air Pollution Control District Board of Directors approved a new rule enabling industry to offset new or increased emissions from stationary sources with emission reductions from mobile sources. Because of declining potential for offsets from the region's stationary sources, the APCD Board recognized there was substantial demand for cost-effective credits from mobile sources. Motor vehicles contribute more than 60 percent of the smog-forming emissions in the San Diego air basin, and industry contributes less than 15 percent.

Rule 27 allows emission reduction credits from motor vehicles to be registered as "credits" in a District "Bank." Industry can withdraw or purchase these credits later to meet state and federal Clean Air Act offset requirements.



Logo of the South Coast AQMD

The rule specifies five ways mobile source emission credits can be created, including:

- Accelerating vehicle retirement (scrapping program)
- Purchasing low-emission transit buses (primarily compressed natural gas)
- Purchasing zero emission (electric) vehicles
- Retrofitting cars, and light- and medium-duty trucks to meet low-emission standards
- Retrofitting heavy-duty vehicles to meet low-emission standards

The rule also provides for other innovative technologies that create valid mobile source emission reductions.

The APCD currently has a program with a private contractor to purchase and scrap 1,000 pre-1982 vehicles. As of December 1994, the program is roughly 60 percent completed and should end in early 1995. If the market dictates, Rule 27 provides a mechanism to continue the program under private funding.

## San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD)

REMOVE is the acronym that stands for "Reduce Motor Vehicle Emissions," a program of the SJVUAPCD, which serves Fresno and the Valley portions of Kern, Kings, Madera, Merced, San Joaquin, Stanislaus and Tulare Counties. The program was formerly known as "AB2766."

REMOVE is an innovative program that allocates fees collected from motor vehicle registrations for local projects designed to reduce air pollution. These funds must be applied to projects that reduce emissions from automobiles, trucks and buses. More than 280 proposals have been considered for funding by the SJVUAPCD since the inception of the program, with more than 90 projects funded from 1992 to 1994.

The SJVUAPCD Governing Board created a committee of 14 citizens to evaluate and recommend projects for funding. The evaluation committee for the REMOVE program develops criteria for evaluating proposals. The committee also rates and ranks the proposals and makes project funding recommendations to the Governing Board. The Board then makes final funding decisions.

Local government agencies, private sector businesses



San Joaquin Valley Unified Air Pollution Control District

non-profit agencies and research institutions are among those eligible to apply for funding. Anyone proposing an effective project to reduce emissions from motor vehicles is encouraged to apply. In December 1994, requests for proposals (RFP) were made available for applicants to apply for the third annual cycle of funding. To receive an RFP, call the District at 209-497-1075.

As required by state law, the fees for the REMOVE program are collected by the California Department of Motor Vehicles and provided to the SJVUAPCD for distribution. In 1994, projects approved by the Governing Board were awarded a total of \$4.77 million. Alternative fuel vehicles received 36 percent of the funding, followed by transportation control measures with 35 percent; plans, studies and research with 18 percent; and public education with 12 percent.

Some of the projects funded in 1993-1994 included:

- The conversion of more than 200 vehicles throughout the district to operate on cleaner-burning alternative fuels
- A variety of studies on a number of topics including the adverse health effects of particulate matter such as vehicular dust emissions, and a light rail corridor
- Transportation control measures that implement bike plans, improve traffic flow and subsidize transit passes
- A district-wide auto buy-back program that will crush more than 700 pre-1975 heavily polluting vehicles
- Transit projects such as free downtown shuttle service

## State & Federal Incentives for Alternative Fuel Vehicles

Most alternative fuel vehicles currently cost more than regular gasoline because of the limited number of vehicles manufactured and because of the additional components that must be added (such as storage cylinders or extra fuel tanks). This will probably change as more AFVs are mass produced. To offset this differential or incremental cost of equipping vehicles to run on alternative fuels, various government agencies and a number of utility companies offer tax credits or deductions, and incentives to the purchasers.

Below are the incentives offered for 1996 model year alternative fuel vehicles.

### California LEV Tax Credits

For the tax years beginning on January 1, 1991, and before January 1, 1996, state law (Senate Bill 2600 [Vuich, Chapter 1611, Statutes of 1990]; which was amended by Senate Bill 1071 [Kopp Chapter 768, Statutes of 1992] and by Senate Bill 146 [Lewis, Chapter 875, Statutes of 1993]) allows a state tax credit for the **incremental cost** of specified “low-emission” vehicles and “low-emission” retrofit devices.

The vehicle or device must be certified by the California Air Resources Board (contact the Energy Commission for latest list of certified vehicles), and all qualifying vehicles also must be registered in California. The incremental cost is determined by the California Energy Commission.

The state tax credit is for 55 percent of the **incremental cost** of a vehicle, or the cost (including installation) of a retrofit device, certified to meet the ARB low-emission requirements.

If there is no additional or incremental cost when compared to a gasoline-only vehicle, then the state tax credit does not apply. For example, if there is no cost charged by the manufacturer for the “low-emission” model then the credit does not apply.

**The state tax credit is a maximum of \$1,000** per automobile, motorcycle or two-person passenger vehicle; or \$3,500 for a vehicle weighing more than 5,750 pounds.

If a federal tax **credit** is enacted for “low-emission” vehicles, the state credit is partially reduced by the amount of the federal credit. Funding for the state tax credits totals \$750,000 for each year (1991 – 1998) and is available with prior certification by the California Energy Commission.

The taxpayer must submit to the California Energy Commission a **Plan to Purchase Form** and also a completed **Purchase/Installation Form**. If the Energy Commission verifies **in writing** that the vehicle is eligible for the credit, the purchaser would then be entitled to submit a **Form 3554** with their State Income Tax.

### Federal Tax Credits and Deductions

The National Energy Policy Act (EPAAct), signed by President Bush on October 24, 1992, contains major provisions for clean and alternative fuel vehicle federal tax credits and deductions. The fuels that are covered by EPAAct are electricity, ethanol, methanol, natural gas and propane.

The law allows a tax **credit** of 10 percent of the cost of electric vehicles. The credit is based on the purchase price of the vehicle and may not exceed \$4,000. The credit is available to vehicles placed into service after June 30, 1993, and prior to January 1, 2005. The federal tax credit is reduced by 1/4 in 2002, to a maximum of \$3,000; 1/2 in 2003, to a maximum of \$2,000; and 3/4 in 2004, to a maximum of \$1,000. It is no longer available after 2004.

The IRS Form is 8834 – Federal Qualified Electric Vehicle Tax Credit.

EPAAct allows for a maximum of up to \$2,000 federal tax **deduction** for clean-fuel vehicles that use clean fuels such as ethanol, methanol, natural gas or propane (liquefied petroleum gas or LPG). The federal tax deduction is based on the **incremental cost** of equipping the vehicle to use the clean fuel; the amount above the price of a regular gasoline-only vehicle. The federal deduction is available for vehicles placed into service after June 30, 1993, and before January 1, 2005.

A \$5,000 federal tax **deduction** is available for alternatively-fueled trucks/vans weighing between 10,000 and 26,000 pounds. A \$50,000 tax deduction is available for alternatively-fueled trucks/vans weighing more than 26,000 pounds, or for buses that can seat at least 20 passengers. The federal deduction is available for vehicles placed into service after June 30, 1993, and before January 1, 2005.

A federal tax **deduction** of up to \$100,000 can be claimed for clean fuel refueling sites (including electricity). The federal tax deduction is available on sites placed into service after June 30, 1993, and prior to January 1, 2005.

## Additional Incentives for AFVs

Please check with the California Energy Commission for any additional incentives that may be offered on alternative fuel vehicles. Call the Transportation Technology and Fuels Office at (916) 654-4634.

Investor-owned natural gas and electric utility companies may be reducing their rebates or incentives in the future. Recent directions by the California Public Utilities Commission on how much can be spent by the utilities and the “down-sizing” and “restructuring” of utility companies, mean that less rate-payer money may be used toward AFV incentives and rebate programs. Some municipal utility districts may also offer incentives for vehicles.

Some current incentives (as of March 1996) include:

- Sacramento Metropolitan Air Quality Management District offers \$200 of methanol fuel (M85) for Fuel-Flexible Vehicles.
- South Coast Air Quality Management District is offering \$5,000 rebates on electric vehicles sold in 1996-1998.
- A \$5,000 electric vehicle incentive is available from the California Energy Commission and the “EV California” program.
- An incentive of \$1,000 to \$1,500 is offered on Natural Gas Vehicles from the Energy Commission (depending on certification level of NGV).

For more information about the state’s Low-Emission Vehicle Tax Credits, please **WRITE**:

**California Energy Commission  
Low-Emission Vehicle Tax Credits  
1516 Ninth Street, MS-41  
Sacramento, CA 95814**

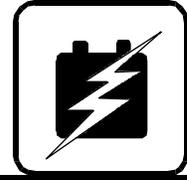
For information on the federal tax credits or deductions, **contact your local Internal Revenue Service Office.**

Please also contact your local air quality district and utility company for information about possible incentives they may be offering. Phone numbers for the major air quality districts are listed on the map on page 20.

# Chapter 3

## Electric Vehicles

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In the words of a reporter from the *Chicago Tribune*, “The electric car is an idea whose time has come.....again.”

Electric vehicles (EVs) have been around since the 1830s before they virtually disappeared in the 1920s.

At the turn of the last century, there were more electric vehicles on the road than there are today. And by the turn of the next century, EVs are expected to make a comeback.

### History of Electric Vehicles

The electric vehicle has a much longer history than most people realize. According to the book *The Green Car Guide*, the first known electric car was a small model built by Professor Stratingh in the Dutch town of Gröningen in 1835. But the first practical electric road vehicle was probably made either by Thomas Davenport in the United States or by Robert Davidson in Edinburgh in 1842.

These pioneers had to use non-rechargeable electric cells. An electric vehicle did not become a viable option until the Frenchmen Gaston Plante and Camille Faure respectively invented (1865) and improved (1881) the storage battery.

The performance of “La Jamais Contente” in 1899 brought the potential of the electric car to the attention of an enthralled world. This was the name for the unique streamlined racing car in which the Belgian Camille Jenatzy broke the world land speed record in France, the first car to go faster than 100 kph (62 mph).

### EVs Today

Electric vehicles have been in continual use since the 1910s in various applications: working in industrial plants, where internal combustion engine exhaust could endanger worker health; on golf courses, where quiet operation adds to the relaxing environment; on worksites to ferry employees between buildings; and on college campuses. But today these quiet vehicles

wil now tailpipe pollution are no longer overgrown golf carts. New advances in battery technology, system integration and aerodynamics, and commitments to research and development by major vehicle manufacturers will soon be producing electric vehicles that will play a practical role on city streets.

Several California cities use electricity to power buses, streetcars and mass transit, although some of these vehicles use an exterior power source like overhead wires (such as San Francisco’s more than 300 electric buses and trolleys, and Sacramento, San Diego and San José’s light rail systems). EVs and electric buses that use internal power sources, however, are also on California’s roads. In May 1993, the California Department of Motor Vehicles had registered 2,877 electric-powered vehicles. This number is slightly misleading, however, because it counts all the vehicles that were registered — including golf carts and fork lift trucks that needed to be licensed. In 1995, the Electric Vehicle Association of the Americas estimated a total of 587 highway-operated EVs in California, excluding San Francisco Muni’s electric trolley buses. The U.S. Department of Energy’s Energy Information Administration estimated the number of EV-autos at 850 in 1995. The number, however, will increase as auto companies bring the cars to the market.

Some EVs now being demonstrated have a range of up to 100 miles, which according to Caltrans trip data, is equal to three times the miles traveled daily by about 60,000 of the 150,000 commercial, light-duty fleet vehicles in Southern California.

According to the Northeast Sustainable Energy Association (NESEA), range records have increased from 35 miles to over 200 miles in six short years at the American Tour de Sol electric vehicle race. NESEA says that the range of EVs using lead acid batteries as their storage system, increased to 142 miles, as shown by a Fiat converted to electricity driven at the 1994 race.

Ranges of more than 150 miles have been achieved with nonspecialized EVs. A Solectria *Force*, a Geo Metro conversion, drove 214 miles using a nickel-metal-hydride battery built by Ovonic Battery of Troy, Michigan. Ovonic plans to have that battery on market by 1998.

According to reports in *Green Car Journal*, an electric car called the IZA produced by Tokyo Power Company, Meidensha and Tokyo R&D claimed a single charge distance of 343 miles in Japan. This was performed on a chassis dynamometer at a constant speed of 25 mph. In 1992, a Horlacher Sport EV powered by sodium-sulfur batteries ran 340 miles nonstop at an average speed of 74 mph in Switzerland.

Acceleration is improving as the technology matures and as systems are more skillfully integrated and managed. Freeway driving speeds will be usual for most full-sized, factory-produced EVs. *The Los Angeles Times* reported that "AC Propulsion, a small California company run by engineer Alan Cocconi, showed off a 200-horsepower EV at the 12th International Electric Vehicle Symposium in Anaheim (in December 1994). The car can do zero-to-60 in 6.2 seconds"...acceleration many gasoline-powered vehicle owners would envy. And the world record top speed for an electric-powered vehicle is 183.075 mph done in the summer of 1994 by a specially modified GM Impact, the prototype EV first unveiled by General Motors in 1990.

Electric vehicles may be the choice for many California urban commuters as a second car. A 1994 poll of Californians done for the prestigious *Automobile Week* magazine says that 63 percent of Californians would buy an electric vehicle. Other polls in the past say that we are likely to buy EVs...if the price is right. Newer polls, including one done by the California Institute of Transportation Studies at the University of California, Davis, echo those earlier polls.

The South Coast Air Quality Management District in 1994 said it expected 19 percent of all light-duty passenger vehicles and seven percent of the light-duty trucks in that district would be ZEVs by 2010 (a total of more than 2.5 million vehicles in Southern California). This number, however, may be highly optimistic especially in light of the relaxation of the ARB ZEV mandate.

The Energy Commission calculates fewer EVs statewide, saying in its *1993 CalFuels Plan* that a total of 1.3 million electric vehicles may be in all of California by 2010. By that year, electric vehicles could consume an estimated 7,483 gigawatt/hours of electricity – about 3.2 percent of the total electricity consumed by California in 1993.

Most EVs will recharge during off-peak hours (such as overnight). Off-peak recharging makes use of electric power plant capacity that normally would sit idle. Few people are using electricity overnight, so the plants are either shut down or scaled back to low output levels. Using these idle power plants would

make the electricity system more efficient overall, thus helping to stabilize electricity rates.

According to the Commission's *CalFuels Plan*, investor-owned and municipal utilities estimate that they can meet the electricity demand for EVs with little or no additions to their generation or transmission systems for the next 15 years. These estimates assume that most of the recharging will occur off-peak. Assuming EV demand is managed, only about 4.5 percent of EV charging will occur on-peak (during the afternoon and early evening).

Southern California Edison estimates that it will need to add only 200 megawatts of capacity by 2008 to accommodate EVs. Such capacity can be made up by saving energy elsewhere (demand-side management) rather than having to build new power plants. Other utilities found no need to add generation capacity or transmission lines to meet EV energy demand in the next 15 years.

## EV Emissions

There are zero **tailpipe emissions** associated with electric vehicles, and even when California and out of state power plants are figured into the air pollution, ZEVs may be up to 97 to 98 percent cleaner than gasoline-powered vehicles (depending on the type of emission). In other states that rely on coal and petroleum for their electricity, the vehicles may not be as clean as in California.

California's electricity production is diverse. More than one-quarter of our electricity comes from renewable resources — hydroelectric, wind, solar, geothermal and biomass — that produce little or no emissions. Most of the state's electricity comes from clean-burning natural gas.

Like our transportation sector is today, California's electricity production was heavily dependent on petroleum. Twenty years ago, more than 50 percent of our electricity came from burning oil in power plants. California recognized that this put the state at risk economically whenever there were fluctuations in the price and supply of oil. The state recognized that oil-fired power plants were heavy air polluters. So, the electric utility industry converted to other cleaner (and at the time, less expensive) fuels. Today, less than one percent of our electricity comes from burning petroleum.

The state is now applying that policy of diversification to the transportation sector with its move toward clean, alternative fuels.

## EVs in Fleets

One of the key concerns when fleets consider buying EVs is certification. The California Air Resources Board certifies which vehicles will meet its Low Emission Vehicle requirements. Currently certified vehicles are listed below. Many fleets have begun using smaller utility EVs, such as meter reader and service vehicles. The lifespan of an EV may be longer than a conventional vehicle because there are fewer parts that break down and lower expected maintenance costs. This could help offset the higher initial costs of an EV. Battery replacement costs, however, may be one of the bigger stumbling blocks for fleet purchases. Newer generations of batteries may help to overcome that drawback.

## Questions & Answers About Electric Vehicles

**When will EVs be in California?** Electric vehicles are already in California. According to best estimates, there are about 600 to 850 vehicles registered as EVs in 1996.

**Are EVs being sold?** A few EVs are being sold by a number of up-fitters, conversion companies or specialty car companies that sell converted gasoline vehicles or purpose-built EVs. Other companies/dealers sell smaller neighborhood electric vehicles (NEVs). NEVs are usually small one or two seaters with top speeds of about 35 to 40 mph.

**What about the major auto companies?** In 1996, General Motors announced it would begin selling its *EVI* (formerly called the GM "*Impact*") at a limited number of Saturn dealerships in Southern California and in Phoenix, Arizona. The price tag for the *EVI* is in the mid-\$30,000 range. The company also plans to sell an EV pickup truck based on its Chevrolet *S-10* model. Ford is selling a limited number of an EV version of its *Ranger* pickups. Other auto companies are demonstrating prototype EVs, but are not currently offering any for sale.

**Does an EV have an engine?** No. EVs do not have an internal combustion engine. EVs are powered by one or more electric motors that are fueled by stored electricity. In common automotive parlance, however, "electric vehicles" refers to all vehicles with electric propulsion. So, the category of "hybrid" vehicles with an on-board means of generating electricity —

including internal combustion generator, fuel cells, etc. — may be considered a sub-category of EVs. The Air Resources Board, however, has yet to determine whether a hybrid vehicle will qualify as a Zero Emission Vehicle.

**How are EVs different from regular internal combustion vehicles?** According to CALSTART, the advanced transportation consortium in California, 70 percent of an electric vehicle's component parts may be different than a conventional vehicle. An EV (except for hybrids) has no internal combustion engine, no liquid fuel tank, no fuel lines, no carburetor, usually no radiator, and many other components.

### **Will EVs create jobs for California companies?**

Many people say they will, which is one reason they are supported by a broad consortium of government agencies, companies and local government bodies. EVs have some high-tech equipment that is often associated with the aerospace and defense industry. So, many jobs that were lost in California because of down-sizing of national defense-oriented companies could be recouped in production of EV components. CALSTART estimates that producing EV components in California could create as many as 40,000 jobs.

**What type of batteries are being used in EVs?** In advanced conversions and prototypes like the General Motors *EVI*, batteries are likely advanced, sealed lead-acid. We may see more advanced batteries in the next century. These could include: advanced, sealed lead-acid; nickel-metal-hydride; nickel-cadmium; sodium-sulfur; zinc-air; lithium-metal-disulfide; sodium-nickel-chloride; lithium-ion; ultra-capacitors and others. The U.S. Advanced Battery Consortium, a coalition of the federal government and the big three American auto companies, has been created to do advanced research on battery technologies.

**How far can an EV go?** As in a conventional vehicle, range depends on a number of factors. In an EV, range depends on the type of batteries, the number of batteries, battery condition, the driving conditions, terrain, climate, whether driving is in the city or on the highway, the driver, and the vehicle itself. Many EVs today have a range of between 60 to 100 miles. According to the California Air Resources Board, when EVs hit the market in 1998, they will probably have a range of about 100 miles before needing to be recharged.

**How do you recharge an EV?** An EV is usually plugged into some type of electrical connector at the

owner's home. This can be a regular 120 volt wall outlet (which is must less effective) or a 220 volt / 40 amp line ( like the type used for electric stoves and clothes dryers). Eventually, fast-charging public charging stations will be available. The vehicle draws current from the electrical source and stores that energy in the battery system. There are currently two types of recharging "plugs:" an inductive charging connector, made by the General Motors subsidiary Hughes Power Systems, and a conductive charging connector, supported by Ford and Chrysler. Decisions will have to be made as to which system will be used by EVs. Some liken the debate between inductive and conductive to the VHS versus Beta fight for video cassette recorders.

**How long does it take to charge an EV?** Most EVs will normally be recharged in three to eight hours, depending on the charging voltage (110 or 240 volts) and how "drained" the batteries are. Quick-charging technologies would provide 60 to 80 percent of the charge to high-charge-density batteries (20 to 60 kilowatt/hours) in five to 15 minutes. Quick-charging technology prototypes have been developed but will require significantly more development and testing before commercialization.

**How much do EVs cost?** Limited production EVs made by specialty companies today are priced in the \$20,000 to \$40,000 range. One company is currently offering an two-seater fiberglass EV sports car with a range of 60 to 80 miles for about \$16,000. When EVs are in full-production by early next century, the price should be in the \$30,000 range, maybe slightly higher than the average car you can buy today.

**Can a gasoline vehicle be converted to an EV?** Yes. Many EV pioneers, such as members of the Electric Automobile Association, have been converting gasoline vehicles or building "kit" EV cars for many years. EV conversion kits are sold for some popular cars such as VW Rabbits, Honda Civics and other lighter cars. A number of companies sell these conversion kits and step-by-step instructions for building an EV. Remember, however, that EVs store a tremendous amount of electricity in their batteries. One could be seriously injured through an electrical shock if precautions are not taken. One should read up about safety around electricity before beginning such a project. Also, a converted car does not necessarily meet federal crash safety tests, and the buyer should carefully consider this prior to purchase.

**How much does a conversion/kit cost?** Kits can range from about \$4,000 to \$5,000 on up — plus the cost of the batteries — to vehicles that have already been converted for tens-of-thousands of dollar, not including the cost of the gasoline vehicle's shell. Taking out the engine and drive train and selling that for parts may recoup some of the cost of the conversion kit.

**What is the cost per mile of running an electric vehicle?** It depends on the initial cost of the fuel. The price can run from five cents a kilowatt/hour (kWh) of electricity for off-peak charging (overnight) to up to 35 cents per kWh for charging during peaks hours at an "opportunity charger." This equates to 1.5¢ to 10.4¢ per mile. Gasoline, by comparison is about 4.0 cents per mile at \$1.19 per gallon and a vehicle getting 29.7 mpg. Most EV customers, however, should be able to get the lower overnight charging rates...so their cost of operating the vehicle could be very low. The maintenance costs for an EV could also be lower than their conventional gasoline counterparts. The replacement cost of batteries, however, may offset this lower cost per mile.

**What is opportunity charging?** This is when you can plug an EV into a metered plug-in connector, such as at a store or parking garage and charge your vehicle during the daytime away from the home base. You could be billed for the convenience of "charging up" your battery, or "free charging" could one day be a marketing incentive for shopping malls or downtown areas. If you are to pay, you could use a coin- or credit card-operated meter, or you could pay an attendant. Some opportunity charging stations have already been set up in municipal garages, but vehicles are not being charged for the small amounts of electricity they are using.

**Do you have to replace the batteries? How often?** Batteries will have to be replaced after a period of time. Constant cycling of the batteries, or just their calendar life, can deplete its ability to store electricity. How often replacement will occur depends on the battery type, the climate and how much the vehicle is driven. Today, most battery pack's useful life is about three years. Replacement cost for the batteries depends on the type and number of batteries but could cost thousands of dollars.

**How much will the battery pack replacement cost? Won't batteries add to landfills?** Again, it depends on the battery type, etc. The price of battery packs varies by type. Most lead-acid batteries are currently recycled. We recycle more than 90 percent of lead-acid batteries

in the country. The acid is drained from the battery, cleaned and recycled as electrolyte in new batteries, the lead is taken out and reused, even the plastic case can be recycled. When EVs become more commonplace, the amount of batteries needing to be recycled will increase – creating more jobs and economic opportunities. Each proposal for government funding for advanced batteries must include a recycling plan.

**What about the recent study by Carnegie Mellon University about increased lead emissions expected to occur as a result of production, manufacturing and recycling of lead acid batteries?** Serious doubts have been raised about the basis of the study by many scientists, including those at the Air Resources Board. The study was widely quoted in the news media. Scientists critical of the study says it used flawed data and according to the Electric Vehicle Association of the Americas, the study has “an alarming series of miscalculations and unsubstantiated ‘guesstimating’.”

**What other maintenance does an EV require?** Newer, sealed batteries do not require watering like older-style lead-acid batteries, but because an EV has fewer moving parts, you will not have to do oil changes, transmission fluid changes, etc. like you would with a conventional vehicle. Other vehicle maintenance, such as wipers and safety equipment will have to be checked no matter what fuel is powering the vehicle.

**What about EV safety?** Concerns do exist over safety with EVs. Batteries will usually be completely sealed, but there is a chance of leakage of acid (in lead-acid batteries) in case of a collision. Some lead-acid batteries use a paste or gel rather than a liquid acid, further making them less likely to spill. There are also concerns over the possible presence of flammable, toxic or corrosive materials in EV batteries – safety training will have to address this. Problems of electrical dangers in charging, and training of personnel in commercial repair garages and service centers will also have to be addressed. Many of these issues are being discussed by industry working groups of the electric utilities, private companies, government agencies and research organizations to solve the concerns before EVs come to market.

The extra weight of the vehicle because of the mass of the battery pack will also have to be taken into consideration when EVs are crash tested.

New building and fire codes have been developed for EVs for 1995-1996. Please contact the Energy Commission for more details.

## Electric Vehicles Currently On the Road

EVs produced by a number of specialty car companies (based on kits, conversion of gasoline vehicles or limited production models) are available to the general public and fleets. These vehicles typically use lead-acid batteries, have limited to medium ranges and do not as yet come with major automakers' warranties. They can cost around \$25,000 to \$40,000 or more. Two of the larger firms that build conversions and specialty EVs are Solectria in Waltham, Massachusetts, and U.S. Electricar in Santa Rosa, California. Solectria announced at the 12th Annual Electric Vehicle Symposium in December 1994, that it will be building a brand new, four passenger EV called the *Sunrise* and selling it for about \$20,000.

The “Big Three” American and foreign car companies are all working on EVs. General Motors electric passenger car is the *EVI* (formerly called the “*Impact*”), which can achieve a speed of 75 miles per hour, accelerate from 0-60 in 8 seconds, and travel as much as 70 to 90 miles before needing a recharge. In early 1991, GM announced that it will produce the electric vehicle in Michigan at the former assembly plant for the Buick *Reatta* but may use a *Corvette* assembly plant. GM originally planned limited production of an *Impact*-like EV by 1995 but delayed introducing the vehicle for sale to the public until the late 1990s. In January 1996, GM announced it would offer the *EVI* for sale beginning in the fall of 1996 at Saturn dealerships in Southern California and in Phoenix, Arizona. Price is estimated at \$35,000. The vehicle may only be available (at first) as a lease.

GM produced approximately 50 pre-production *Impacts* to loan out to more than 1,000 electric utility customers in 12 cities around the country for two to four weeks in a special test program. The *Impacts* were test-driven by electric customers in Los Angeles, Sacramento, San Diego and San Francisco.

Ford Motor Company has produced the *Ecostar*, a European *Escort* Minivan retrofitted with an electric power train and using sodium-sulfur batteries for testing purposes. The *Ecostars* have logged hundreds of thousands of miles in a test of more than 100 vehicles in delivery fleets around the country. Ford has not said whether or not it will offer an EV in 1998, or what model it will offer.

Ford recently announced it would supply EV conversion companies with pickup “gliders,” a vehicle chassis without the power train, based on its *Ranger* pickup truck. This can cut the cost of an EV made on a converted gasoline vehicle by up to 30 percent. Ford

has also announced that it will also sell a limited number of its *Ranger EVs*.

Chrysler has announced that it will begin selling its *NS-Electric* in 1997. The vehicle is based on an all new version of its popular *Caravan* minivan and is expected to be on sale in 1996. Prototypes with advanced lead acid batteries have been driven with 60 mile ranges. Nickel-metal-hydride powered *NS-Electric* minivans have been demonstrating a range of 90 miles in testing

Foreign manufacturers are also working on EVs for the California market. Nearly all of them, including some not impacted by the ARB standards, have premiered electric vehicles at auto shows in California, but most have been secretive about their plans to meet the Zero Emission Vehicle standards.

According to recent media reports: Toyota will probably sell an electric version of its *RAV-4*, a popular small sport-utility vehicle that is sold in Japan and just introduced in early 1996 to the United States. The car has a top speed of 75 mph and a range of 70 miles. A number of *RAV-4s* are expected to be in placed in demonstration fleets in 1996.

Honda has been running a demonstration program with eight *CUV-4s*, a Honda *Civic* hatchback EV. They are in fleet use with Pacific Gas and Electric Company and Southern California Edison. Honda says it will probably redesign a body for its EVs.

Peugeot may introduce an EV in the U.S. Their EV is currently under going testing in France. Its estimated price tag is \$12,000.

Renault is currently testing a dozen EV prototypes, including the *Soterem* hybrid, made by a small French aerospace company.

PIVCO, a Norwegian-led consortium, is hoping to bring an under-\$10,000 light-weight EV to market in the U.S. The *CITI*, standing for Clean Intelligent Transportation Inc., is a two-passenger vehicle that is being used in station car tests in the San Francisco Bay Area. PIVCO is expecting to open a California-based manufacturing plant that will build vehicles for U.S. consumption. The *CITI* has a range of 65 miles in urban driving, a top speed of 55 mph, and a charging time of five hours at 110 volts. The vehicle is powered by a 30 kilowatt Brusa AC induction motor.

Other European car companies are also working on EVs. BMW and Mercedes have both shown prototype EVs at California auto shows. Volvo officials, however, say they will not sell a battery-only EV. The company is working on a special hybrid that uses a gas turbine generator to produce electricity to power electric motors and charge batteries. The Volvo *Environmental Concept Car (ECC)* was unveiled at the Greater Los Angeles Auto Show.

One the next page is a list of new and used EVs that have been certified by the California Air Resources Board, as of December 1, 1995.

## Current Air Resources Board – Certified Electric Vehicles

(As of December 1, 1995 – latest list available at “press time”)

- Advanced Electric Car Technology Inc. - three 1993 & 1994 models (conversions)
- Blue Bird Body Company - 1994 TCEV 3204 School Bus
- Chrysler TEVan - 1993/1994 Dodge Caravan/Plymouth Voyager
- CityCom Elektromobilfabrik A/S - 1993/1994 City-EL, (Neighborhood EV)
- Cushman - 1993/1994/1995 “ZEV” meter reader utility vehicle
- Doran - 1992 EcoScoot electric motorcycle (similar to Hona Elite)
- Drive Electric - nine 1993/1994 models (conversions)
- Ford Ecostar - 1993 limited production
- GM Impact 3 - 1994 limited production
- Green Motorworks - Kewet El-Jet (Neighborhood EV)
- Nordskog - 1993 LT02 electric shuttle bus
- Renaissance Cars Inc. - 1995 Tropica (*note: company may be out of business*)
- Solectria - “Force” EV - four 1991/1992/1993 models (conversions)
- Specialty Vehicles - four 1993 models of shuttle buses
- U.S. Electricar (Solar Electric) - 11 1992/1993/1994 models  
(conversions & purpose built)
- Westward - GO-4E (three-wheel “police” electric motorcycle)

Note: As of December 1, 1995, there were also 25 approved electric vehicle conversion kits for various makes, models and years (1975 to 1996 model years) of internal combustion engine vehicles and motorcycles. Please contact the California Air Resources Board at (916) 322-2990 for the latest list of certified kits and their manufacturers.

## EV Contact List

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The following list is provided as a public service by the California Energy Commission. It is not intended as an endorsement of any product, company or service. The California Energy Commission, its management and staff make no claims, implied or otherwise, about the information listed here. We apologize for any errors that may occur.

This list is also provided and updated regularly on the Energy Commission's Internet site. The address (URL) of the Commission's Homepage is: <http://www.energy.ca.gov/energy/>

Please send corrections of updates via Internet e-mail to [boba@energy.ca.gov](mailto:boba@energy.ca.gov) or by regular mail to:

Bob Aldrich  
Information Officer  
California Energy Commission  
1516 Ninth Street, MS-29  
Sacramento, CA 95814

### Automakers, Battery, Equipment & Conversion Companies

AAI Corporation  
Attn: R. Conrique  
P.O. Box 126  
Hunt Valley, MD 21030-0126  
410-628-3477  
(private-public defense transportation industries)

AC Propulsion  
Alan Cocconi  
462 Borrego Ct., Unit B  
San Dimas, CA 91773  
909-592-5399  
FAX 394-4598  
(conversion kits, propulsion systems)

Advanced Vehicle Systems  
Joe Ferguson  
3101 Parker Lane  
Chattanooga, TN 37419  
615-821-3146  
(manufacturer of Electric Buses)

American Flywheel Systems  
Hunts Point  
Bellevue, WA  
206-454-1818  
(flywheel storage system - in development)

American Monarch Corporation  
2801 37th Ave., N.W.  
Minneapolis, MN 55421  
612-788-9161  
(quick battery exchange systems, chargers)

Amerigon  
Josh Newman  
Vice President  
425 E. Huntington Drive  
Monrovia, CA 91016  
818-305-1100  
(EV passenger heating/cooling, advanced EV component design)

Amp King Battery / Trojan Corporation  
Jim Phillips  
Information Officer  
10 Loomis Street  
San Francisco, CA 94124  
415-648-7650  
E-mail: [JPhill6255@aol.com](mailto:JPhill6255@aol.com)  
(lead acid batteries, chargers, advice)

APS Systems  
Ed Atelia, Chairman  
3535 West Fifth Street  
Oxnard, CA 93030  
805-984-0300  
(EV shuttles and buses)

Auburn Scientific Company  
P.O. Box 2150  
Carmichael, CA 95609-2150  
FAX: 916-944-0301  
E-mail: [AuburnSci@aol.com](mailto:AuburnSci@aol.com)  
(EV components, controllers)

Avcon Corporation  
1935 Ace World Wide Lane  
Cudahy, WI 53110  
(EV connectors, plugs, etc.)

Baker Electromotive  
Skip Baker  
Summit Avenue at Norfolk Street  
Richmond, VA 23260  
804-358-0481  
(EV converter, GMC Sierra p/u trucks)

B.A.T. International Inc.  
Joe LaStells, President  
Bob Martino, VP  
3601 Empire Ave.  
Burbank, CA 81505  
818-565-5555  
Internet: [B\\_AT\\_565@aol.com](mailto:B_AT_565@aol.com)  
(EV converter/manufacturer)

Batteries Plus  
5960 Scarborough Blvd.  
Columbus, OH 43232  
614-577-1998  
(batteries and more)

Beetles Unlimited  
19804 Aurora Ave. N.  
Seattle, WA 98133  
206-546-1803  
(converter - mainly restores gas VVs)

Beyond Oil  
P.O. Box 99  
Mill Valley, CA 94942  
(conversion kits)

BIS Strategic Decisions  
40-44 Rothesay Road  
Luton LU1-1QZ  
ENGLAND  
44-1-582-405678  
(advisers on info technologies)

Blue Bird Body Corporation  
3920 Arkwright Road  
Macon, GA 31210  
912-757-7100  
(electric & natural gas school buses)

David E. Bruderly  
Bruderly Engineering Associates  
1826 N.W. 57th Terrace  
Gainesville, FL 32065  
904-377-0932  
(engineering and design)

California Battery Company  
8646 Magnolia Ave.  
Santee, CA 92071  
619-258-7073  
(battery seller)

California Electric Cars  
Craig Campbell  
1661 Del Monte Blvd.  
Seaside, CA 93955  
408-899-2012  
Internet: [tbrooks@aol.com](mailto:tbrooks@aol.com) via Tom Brooks  
(purpose-built EVs)

Canadian Electric Vehicles Ltd.  
Randy Holmquist  
7647 Superior Rd. Lantzville  
British Columbia, Canada V0R 2H0  
604-390-3364  
E-mail: [canev@islandnet.com](mailto:canev@islandnet.com)  
Internet: [http://www.pitzer.edu/~kester/img\\_cevil.html](http://www.pitzer.edu/~kester/img_cevil.html)  
(conversions, components)

Centerline Engineering  
1612 S. Lyon St.  
Santa Ana, CA 92705  
714-543-9898  
(wire and cable assemblies for EV manufacturers)

A Michael Clement  
Manager  
AFV Sales and Marketing  
Chrysler Corporation  
27777 Franklin Rd., 4th Floor  
Southfield, MI 48034  
810-948-3644

Clearwater Electric Boats Inc.  
17 Palmer Lane  
Riverside, CT 06878  
800-398-2016  
(Charger 40 electric boat)

Corbin  
11445 Commercial Parkway  
Castroville, CA 95012  
408-633-2500  
("Corbin Sparrow" - 3-wheel, freeway capable EV)

Curtis Instruments Inc.  
200 Kisco Ave.  
Mt. Kisco, NY 10549  
914-666-2971  
and  
Steve Post  
Curtis PMC Div of Curtis Instruments  
6591 Sierra Lane  
Dublin, CA 94568  
510-828-5001  
(controllers, gauges)

Cruising Equipment Company, Inc.  
6315 Seaview Ave., N.W.  
Seattle, WA 98107  
206-782-8100  
(instruments, regulators, meters)

DAX Industries Inc.  
Charles Masterson  
9301 Hwy. 290 West  
Austin, TX 78736  
512-301-1144  
E-mail: DAXCONTROL@aol.com  
(patented MOSFET DC motor controllers)

Design Evolution4 Inc.  
P.O. Box 143  
Lebanon, OH 45036  
513-932-3100  
(design, engineering)

Dolphin Vehicles  
P.O. Box 110215  
Campbell, CA 95011-0215  
408-379-2256  
(designer of Vortex 3-wheel, small EV)

Doran Motor Company  
6290 Sunrise Meadows Loop  
Reno, NV 89509  
702-359-7356  
(maker of the smaller EVs: 3-wheeler, go-carts, scooters)

Eagle-Picher Industries Inc.  
Electronics Division  
P.O. Box 47,  
Joplin, Missouri 64802 USA  
417-623-8000  
(Nickel-Iron batteries)

East Penn Manufacturing Co. Inc.  
Lyon Station, PA 19536  
610-682-6361 or 682-4231  
(sealed lead-acid gel batteries)

E-Car Company  
Lou Talbo or Marshal Houston  
2430 SW Scenic  
Portland, OR 97225 USA  
503-254-7612  
Internet: ecar@europa.com  
(specialty conversions with emotion, style and performance)

EcoElectric Corporation  
Mary Ann Chapman  
John Witt  
P.O. Box 85247  
Tucson, AZ 85754  
520-770-9444  
Internet: ecoelec@primenet.com  
Web Site: <http://www.primenet.com/~ecoelec/>  
(EVs, conversions and components)

Eco-Motion  
Steven Lough  
President  
6021 - 32nd Ave., N.E.  
Seattle, WA 98115  
206-524-1351  
Internet: slough@halcyon.com  
Web Site: <http://www.cyberzine.org/html/Electric/ecomotion.html>  
(conversions, consulting)

Electric Car Company  
Greg Shift  
P.O. Box 618  
401 Lincoln St.  
Everson, WA 98247  
800-247-5990 or 206-966-3215  
(purpose built, ground up EV. MI-6 Sports Hardtop Roadster)

Electric Car Company of America, Inc.  
Richard Mayer & Don Eaton  
5730 Tujunga Ave. - P.O. Box 380  
North Hollywood, CA 91603 USA  
818-763-7321  
(kits, components)

Electric Fuel Corporation  
Binyamin Koretz  
Director, Strategic Planning  
885 Third Ave., Suite 2900  
New York, NY 10022  
212-230-2172  
E-mail: ef-info@electric-fuel.co.il  
Internet: <http://www.electric.fuel.co.il>  
(Zinc-Air batteries)

Electric Motor Cars, Sales and Service  
Ken Bancroft  
4301 Kingfisher Drive  
Houston, TX 77035 USA  
713-729-8668  
(components, conversions, technical consulting)

Electric Power Technology Inc. (EPTI)  
6400 Atlantic Blvd. #130  
Norcross, GA 30071  
404-449-1104  
(EV charging stations)

Electric Vehicle Automotive Systems Inc.  
7119 E. Shea Blvd. #109-495  
Scottsdale, AZ 85254  
602-992-0439

Electric Vehicle Infrastructure Inc.  
Mickey Oros, President  
11839 Industrial Court  
Auburn, CA 95603  
916-823-8077  
E-mail: spengs@quicknet.com  
(design and implementation of EV charging stations and peripherals)

Electric Vehicles of America Inc.  
Bob Batson  
48 Acton Street  
P.O. Box 59  
Maynard, MA 01754-0059  
508-897-9393  
(EV conversions, kits, components)

Electric Vehicles Northwest Inc.  
306 S. Michigan  
Seattle, WA 98108  
206-762-4404  
E-mail: evsnw@semac.wa.com  
(conversions, components, engineering design)

Electro Automotive  
Mike Brown & Shari Prange  
P.O. Box 1113  
Felton, CA 95018-1113  
408-429-1989  
(conversion kits)

Electronic Power Technology Inc.  
6400 Atlantic Blvd., Suite 130  
Norcross, GA 30071  
404-449-1104  
(charging stations for EVs)

Electrosource Inc.  
3800B Drossett Drive  
Austin, TX 78744-1131 USA  
512-445-6606  
(makers of the Horizon Battery, improved lead-acid)

Empyreum, Inc. - San Antonio Shop  
Jerry McAlwee  
809 W. William Cannon I-203  
Austin, TX 78745 USA  
210-422-3155  
E-mail: JerryMgt40@aol.com  
(components, kits, conversions. Exotics)

Energy Partners  
1501 Northpoint Parkway, Suite 102  
West Palm Beach, FL 33407 USA  
407-688-0500  
(Hydrogen fuel cells for "The Green Car" - Hydrogen Fuel Cell-based EV)

Environmental Research Group  
Kari A. Reimers  
Research Associate  
376 Greenwood Beach Rd.  
Tiburon, CA 94920  
415-381-9650  
E-mail: karianne23@aol.com  
(research for EV and "green" companies)

EROS Omni  
P.O. Box 96  
Albion, CA 95410 USA  
707-937-4352  
(bicycle/scooter conversions)

EyeBall Engineering  
Ed Rannberg  
16738 Foothill Blvd.,  
Fontana, CA 92336 USA  
909-829-2011  
(conversions, components)

E-Z Red Company  
P.O. Box DV85  
Deposit, NY 13754  
800-522-7947  
(battery testing equipment)

First Inertia Switch  
G-10385 North Holly Rd.  
Grand Banc, IM 48439-1181  
810-669-8115  
(modules and switches)

Fisher Electric Technology  
Geoff McLelland  
Director of Marketing and Sales  
2870 Scherer Drive  
St. Petersburg, FL 33716  
813-572-9422  
E-mail: Fisher@IntNet.net  
(design and manufacturer of brushless DC systems, range extenders, more)

Ford Motor Company  
John Wallace  
Director, Electric Vehicle  
Planning & Program Office  
23400 Michigan Avenue,  
Suite 230  
Dearborn, MI 48124  
313-390-5589

GE Electrical Distribution & Control  
Tracey Harbor - 919-563-7371  
Joe Lambert - 919-563-7370  
Jim Rettman - 919-563-7418  
PO Box 489, 6801 Industrial Drive  
Mebane, NC 27302  
(controllers for DC traction motors)

GM Ovonic L.L.C.  
Electric Vehicle Division  
1675 West Maple Rd.  
Troy, MI 48084  
818-280-1900  
(nickel-metal-hydride batteries)

General Motors Corporation  
Raymond Buttacavoli  
Industry-Government Relations  
515 Marin Street, Suite 216  
Thousand Oaks, CA 91360  
805-373-8495

General Motors Corporation  
Electric Vehicle Program  
Public Relations  
Mail Code 23, 1450 Stephenson Hwy.  
Troy, MI 48007  
810-528-6234

Global Electric Transport Systems  
Bob Ketcheson  
550-M Kalaniana'ole Ave.  
Hilo, HI 96720  
808-965-0224  
(EVs and electric boats)  
E-mail: wfirecan@ccinet.ab.ca  
Internet: <http://www.rtt/ab/ca/rtt/personal/global/global1.htm>

Global Light and Power  
Steve Van Rounk  
520 Pine St.  
Sandpoint, ID 83864 USA  
208-263-5027  
(converter, kits, components)

Goodyear Tire & Rubber Company  
Bill Egan  
P.O. Box 3531  
Akron, Ohio 44309 USA  
216-796-2715  
(low rolling-resistance tires)

G N B Battery Technologies  
375 Northridge Rd.  
Atlanta, GA 30350  
404-551-9157  
(lead-acid batteries)

Great Lakes Electric Vehicles  
47 Sunnyside  
Columbus, OH 43214  
614-899-6263  
(conversions)

Green Motorworks  
Bill Meurer  
President  
5228 Vineland Avenue  
North Hollywood, CA 91601  
818-766-3800  
(full-serve EV store, EVs and conversion kits)

GreenWheels Electric Car Company  
Jeff Kester  
181 Elliott Street, Unit 605  
Beverly, MA 01915  
508-927-7148  
Internet: Jeff Kester (kester@shore.net)  
Web Site: <http://northshore.shore.net/~kester/>  
(complete EV conversions)

Hawker Energy Products Inc.  
4318 Rainbow Bd, #730  
Kansas City, Kansas 66103 USA  
800-730-7733  
(rechargeable batteries "Genesis," finished with lead and tin)

Robert J. Bienenfeld  
Manager, Market Development  
American Honda Motor Co. Inc.  
1919 Torrance Bl.  
Torrance, CA 90501-2746

Hughes Power Control Systems  
Fred Silver  
Marketing Manager  
Loc. TO, Bldg. 237, MS 1450  
3050 West Lomita Blvd.  
Torrance, CA 90509  
310-517-5717  
(inductive charging system for GM EV1)

Inco Specialty Power Products  
J Roy Golden Laboratory  
Sheridan Park  
Mississauga, Ontario  
CANADA  
905-403-2416

Indramat Division of Rexroth Corp.  
Ron Larsen, Marketing Communications  
5150 Prairie Stone Parkway  
Hoffman Estates, IL 60192  
708-645-3600  
Internet: <http://www.industry.net/indramat>  
(AC vector drives for EVs, precision machine and motion controls for industrial automation)

Inductran  
1326 Ninth Street  
Berkeley, CA 94710  
415-526-5590  
(inductive charging equipment)

Japlar/Monarch  
4500 Alpine Ave.  
Cincinnati, OH 45242  
513-791-7192  
(battery charging equipment)

Jetporter Inc.  
Gaylen Springer, Owner  
P.O. Box 4205  
Salem, OR 97302-8205  
E-mail: jetport@cyberhighway.net  
(manufactures EV aircraft tow vehicles and EV drives)

K & W Engineering Inc.  
3298 Country Home Road  
Marion, IA 52302  
319-378-0866  
(battery chargers, tachometers)

Kaylor Energy Products  
20000 Big Basin Way  
Boulder Creek, CA 95006  
408-338-2200  
(conversion kits)

Kerner Industries  
Ken Earnest  
(Dir. Advanced Vehicle Systems)  
890 Fortress St.  
Chico, CA 95926  
916-342-8000  
E-mail: Grant Coblentz  
(grantc@ecst.csuchico.edu)  
(conversions, components, kits, EV sales)

KonneKtech  
Division of K&K Stamping Company  
34230 Riviera Drive  
Fraser, MI 48026  
810-294-7400  
(high amp electrical connectors)

KTA Services Inc.  
944 West 21st Street  
Upland, CA 91784  
909-949-7914  
FAX 949-7616  
(conversion kits, components)

Lake Shore Cryontronics  
64 East Walnut  
Westerville, OH 43081  
614-891-2243  
(encoders, sensors and pulse wheels for AC & DC systems)

Lester Electrical of Nebraska  
Jeff Hatcliff  
625 West A  
Lincon, Nebraska 68522 USA  
402-477-8988  
(Lester battery chargers)

Mathes Electric Motorcar Corp.  
Barry Mathes  
South West Houston, Texas  
713-621-1420  
or  
Ocala, Florida  
904-351-3700  
E-mail: BMV3700@aol.com  
(EV conversions)

MendoMotive Electric Vehicles  
Gary Flo  
Manager Director  
110 W. Elm Street  
Fort Bragg, CA 95437  
707-964-1331  
E-mail: mmotive@mcn.org  
Internet: <http://www.mcn.org/a/mmotive>  
(conversion kits, components)

Mike's Auto Care  
Mike Slominski  
951 S. Claremont St.  
San Mateo, CA 94402  
415-343-8801  
Internet: Mike Slominski  
(evdriver@aol.com)  
(conversions)

Nartron Corporation  
5000 North US 131  
Read City, MI 49677  
616-832-5525  
(DC controllers, sensors)

Next World Design  
6159 Radekin Road  
Columbus, OH 43232  
614-866-9662  
(advanced vehicle & product styling studio)

Newell Data  
411 Frontier Drive  
Erie, PA 16505-2509  
814-455-1959  
(data analysis)

Nordskog Electric Vehicles  
Jamie Lowe  
Marketing Director  
1981 West Redlands Blvd.  
Redlands, CA 92373  
909-793-2891  
(industrial EVs)

North Coast Battery  
12808 Bellaire Rd.  
Cleveland, OH 44135  
216-252-2828  
(batteries, chargers)

Northwest Diversified Services  
10313 Milan Road  
Milan, OH 44846  
419-621-5512  
(design, testing and fabrication of vehicles)

Nu-Kar Electric Vehicles  
Glen Stevens  
710 Highway 57  
Collierville, TN 38017 USA  
800-598-6904 or 901-853-8021  
(conversions, kits, components, manufacturer)

Ohio Semitronics Inc.  
4242 Reynolds Drive  
Hilliard, OH 43026-1264  
614-777-1005  
(instrumentation, EV monitoring systems)

Pacific Electric Vehicles, LLC  
Barry Pearson, President  
Sales and Marketing Office  
8500 Weyand Ave.  
Sacramento, CA 95828  
916-381-3509  
E-mail: BarPearPEV@aol.com  
or  
Pacific Electric Vehicles, LLC  
William Warf, CEO  
Operations, Manufacturing and R&D  
190 Ford Road, Suite 111  
Ukiah, CA 95482  
707-485-5799

Phil Gary Enterprises USA  
8800 Allen Road  
Peoria, IL 61615  
309-693-3300  
(tires and sealants)

Pluskota Electric Manufacturing Co.  
11637 So. Mayfield Ave.  
Alsip Industrial District  
Worth, IL 60482  
708-597-0200  
(battery chargers)

Powertech  
Caston Dalon  
Huntington Beach, CA  
714-846-0980  
Main office 803-328-1888  
(electric motors)

Real Goods  
966 Mazzoni Street  
Ukiah, CA 95482 USA  
800-762-7325 or 707-468-9214  
(mail-order: "off-the-grid" PV + EV parts + green supplies)

RR Electric Car  
2430 Orange St.  
Martinez, CA 94553  
(conversion kits)

Replica Roadsters  
Capt. Glenn Roach  
17508 Delia Avenue  
Torrance, CA 90504  
310-329-6436  
Internet: demcg@genie.geis.com  
(conversions, hybrids)

Reynolds Research and Development  
Advanced Propulsion Systems  
2176 Arkansas  
Oregon, OH 43616  
419-698-8786  
(propulsion systems)

Dr. Alex Ruderman  
Dr. Brushless Consulting  
18 Hajasmin Str.  
Or Akiva 30600  
ISRAEL  
972-840-8085  
E-mail: roderman@iil.itel.com  
(EV and motor consulting)

RUSSCO Electro-Mechanical Engineering  
Russ Kaufman  
P.O. Box 3761  
Santa Rosa, CA 95402  
707-542-4151  
(safety EV heater)

SAFT America Inc.  
711 Industrial Blvd.  
Valdosta, GA 30601  
912-247-2331  
(Ni-Cad battery manufacturer)

Samot Engineering Ltd.  
Alex Sromin  
General Manager  
Bldg. 3 Kiryat Weizman Science Park  
Ness Ziona 70400  
ISRAEL  
972-840-6911  
(designers and makers of custom  
supercompact pancake brushless motors)

Sanden International  
601 South Sanden Blvd.  
Wylie, TX 75098-4999  
214-442-8400  
(EV conversions)

San Diego Electric Automobile Company  
Ron Larrea  
9011 Los Coches Rd.  
Lakeside, CA 92040  
619-443-3017  
E-mail: PHILLIPS@GAV.gat.com  
(conversions and kits, broker for used EVs)

Sevcon Ltd.  
Mark Wilson, Sales Mgr.  
Kingsway, Gateshead  
Tyne & Wear  
England NE11 0QA  
+44 (0) 191-487-8516  
E-mail: sales@sevcon.demon.co.uk  
Internet: <http://www.tcom.co.uk/sevcon>

Solar Car Corporation  
Douglas Cobb  
President  
1300 Lake Washington Road  
Melbourne, FL 32935  
407-254-2997  
Internet: Doug Cobb  
(74601.2205@compuserve.com)  
(conversions, kits, components)

Solarmax Corporation  
1040 Commerce Blvd.  
N. Sarasota, FL 34243  
813-351-6443  
(conversion kits, maker of Contour minivan)

Solectria Corporation  
Karl E. Thideman  
Director of Marketing  
68 Industrial Way  
Wilmington, MA 01887  
508-658-2231  
E-mail: kthideman@aol.com  
(one of the leaders in EV technology;  
designs and produces "Force" EV;  
components and drive systems)

Specialty Vehicle Manufacturing Corp.  
Don Duffy  
President  
9250 Washburn  
Downey, CA 90241  
310-904-3434  
(electric shuttle buses)

Sun Cat Motor Company  
Div. James Kamm Technologies Inc.  
4730 W. Bancroft  
Toledo, OH 43615  
800-676-3013  
(electric scooter, also 3-wheeler EVs)

Suntera  
P.O. Box 341  
Honokua, Hawaii 96727  
808-775-7771  
(manufacturers "Sunray," a simple, two  
seater city EV)

Sun Toys  
1803 Mission Street #50  
Santa Cruz, CA 95060  
800-SUN-TOYS (408-464-8697)  
(conversions, components)

Taylor-Dunn Manufacturing Company  
2114 West Ball Road  
Anaheim, CA 92804  
714-956-4040  
(manufacturer of Industrial EVs, like the  
Elektruk)

TCR Company  
850 North Eolmhurst Road  
Mt. Prospect, IL 60056  
708-259-1777

Tech Systems  
A DATRON Company  
Gene Dombrowski  
Thomaston, CT  
203-283-5801  
(AC and DC drive motors)

Technologies M4 Inc.  
575 LeBreton  
Longueuil, Quebec  
CANADA J4G-IR4  
514-463-6007  
(hybrid powertrain technologies)

Thomas Built Buses  
1408 Courtesy Road  
High Point, NC 27260 USA  
910-889-2589  
(EV School Bus - EVS-12)

Town Creek Industries  
P.O. Box 172U  
Route 2, Suite 1C  
Leonardtown, MD 20650  
301-475-2461  
(electric wheel technology)

Trans2 Corporation  
Jame Thomas, V.P. Sales/Marketing  
12997 Meriman Road  
Livonia, MI 48150  
800-204-T222

Trans Technology Electronics  
8800 Allen Rd.  
Peoria, IL 61615  
309-693-3300  
(cables and wiring harnesses)

Trojan Battery Company  
Rick Godber  
President  
12380 Clark Street  
Santa Fe Springs, CA 90670  
800-9-TROJAN or 310-946-8381  
(manufacturer of deep-cycle lead-acid EV  
bateries)

Turbogen Inc.  
682 Laurel Ridge Dr.  
Gahanna, OH 43230  
614-476-9100  
(turbogenerators)

U.S. Battery Company  
Ron Anderson  
1675 Sampson Ave.  
Corona, CA 91719 USA  
800-695-0945 or 909-371-8090  
(lead acid EV batteries)

U.S. Electricar  
P.O. Box 6645  
Santa Rosa, CA 95406  
707-525-3227  
(manufacturer of EVs, conversions)

Unique Mobility Inc.  
Ray Geddes, Chairman  
425 Corporate Circle  
Golden, CO 80401  
303-278-2002  
(manufacturer of high efficiency motors,  
controls, EVs & hybrids)

Vermont Electric Car Co.  
Hilton Dier III  
Route 3  
Montpelier, VT 05602  
802-223-6652  
E-mail: HiltonIII@aol.com  
(conversions)

VoltAge Inc.  
Bob Hadden  
18422 South Broadway  
Gardena, CA 90248  
310-532-4536  
Internet: Volt45@aol.com  
(propulsion systems, custom EV conversions)

Wallingford AC Controls Inc.  
Tom Faul or Wolf Wagner  
5441 N. W. 15th St.  
Margate, FL 33063  
954-973-4350  
(AC motor controls systems)

Westinghouse  
Joyce Henderson or Tim Winter  
EV Support & Service group  
Westinghouse Electric Co.  
Baltimore, MD  
410-993-6245  
(AC motors)

Whitehall Motors Company  
682 Laurel Ridge Drive  
Gahanna, OH 43230  
614-476-9100  
(mid-size EVs, & HEVs)

Wilde EVolutions, Inc  
Roderick Wilde or Bob Rickard  
P.O. Box W  
Jerome, Arizona 86331  
- or -  
218 Polk Street, Suite 343  
Port Townsend, Washington 98368  
800-Fast-EVs (800-327-8387)  
E-mail: carguys@Wilde-EVolutions.com  
Internet: <http://www.Wilde-EVolutions.com>  
(converter, kits, components)

Howard Wilson  
2050 Mandeville Canyon Road  
Los Angeles, CA 90049  
213-476-4647  
(EV consultant)

Bob Wing  
P.O. Box 277  
Inverness, CA 94937-0277  
415-669-7402  
FAX 669-7407  
Internet: EWing@aol.com  
(EV consultant, writer)

Wyle Laboratories Inc.  
Dave Dougherty  
Director of Program Development  
7800 Highway 20  
Huntsville, AL 35806  
205-837-4411  
E-mail: [service@wylelabs.com](mailto:service@wylelabs.com)  
Internet: <http://www.sylelabs.com>  
(independent testing laboratory)

XCORP  
C.S. Catlin, President and CEO  
P.O. Box 17131  
Beverly Hills, CA 90210  
310-859-9903  
(RD&D of recyclable aluminum and  
advanced polymer matrix materials for EV  
bodies)

ZAP Power Systems  
6933 Nolan Road  
Forestville, CA 95436  
707-887-0479  
Internet: [75462.3062@compuserve.com](mailto:75462.3062@compuserve.com)  
also  
ZAP Power Systems  
Nancy Katterman  
2235 Clementom  
Alameda, CA 94501 USA  
800-251-4555 or 510-523-8103  
Internet: [JimMcGreen@compuserve.com](mailto:JimMcGreen@compuserve.com)  
(75462.3057@compuserve.com)  
(electric bikes/trikes/scooters)

Zinc Air Power Corporation  
Dana Drescher  
President and CEO  
4440 Warrensville Center Road  
Cleveland, OH 44128  
216-586-6565  
(Zinc-Air traction batteries for EVs)

Zutter Electric Vehicles  
P.O. Box 5  
Bowen Island, BC  
CANADA  
604-947-0798  
(EVs and propulsion systems)

## Fuel Providers & Utility Research Organizations

(California and major U.S. utilities -  
please check with your local electric  
utility about its program)

Alameda Bureau of Electricity  
Matt McCabe  
Electric Vehicle Program  
2000 Grand Street  
P.O. Drawer H  
Alameda, CA 94501  
510-748-3901

Consolidated Edison Co. of New York  
Robert A. Bell  
Vice President,  
Research & Development  
4 Irving Place, Room 1422  
New York, NY 10003  
212-460-3882

Duke Power Company  
Donald H. Denton, Jr.  
Senior Vice President  
Planning & Operating  
PB04M, 422 South Church Street  
Charlotte, NC 28242  
704-373-4736

Edison Electric Institute  
Thomas Morron  
Vice President  
Customer Services & Marketing  
701 Pennsylvania Ave., N.W.  
Washington, DC 20004  
202-508-5650

Electric Power Research Institute  
Barbara Kline  
Public Relations Manager  
P.O. Box 10412  
3412 Hillview Avenue  
Palo Alto, CA 94303  
415-855-2000

Electric Power Research Institute  
Arnold Frickett  
VP-Consumer Systems Division  
P. O. Box 10412  
3412 Hillview Avenue  
Palo Alto, CA 94303

Electric Power Research Institute  
Electric Transportation Info Center  
Carol Precobb  
501 14th Street, Suite 210  
Oakland, CA 94612  
800-848-ETIC

Los Angeles Dept. of Water & Power  
Mindy Berman  
Public Relations Office  
P.O. Box 111  
Los Angeles, CA 90051  
213-367-1344  
EV Hotline: 800-552-2334

Los Angeles Dept. of Water and Power  
Tom Doughty  
Director Electric Transportation  
111 North Hope Street, Room 1106  
Los Angeles, CA 90012  
213-481-5698

Pacific Gas and Electric Company  
Roland Risser  
Director, New Energy Markets  
Mail Code H28C  
P.O. Box 770000  
San Francisco, CA 94177  
415-973-8437

Pacific Gas and Electric Company  
Bill Sessa  
Bureau Chief, Corporate Communications  
925 L Street, Suite 890  
Sacramento, CA 95814  
916-446-6616  
(formerly Information Officer for California  
Air Resources Board)

Power Technology  
Jon McGuire  
EV Infrastructure Programme Leader  
Ratcliff-on-Soar  
Nottingham, England  
NG11 0EE  
E-mail: Jon.McGuire@powertech.co.uk  
Internet: <http://www.powertech.co.uk>  
(3rd largest energy generator in UK)

Sacramento Municipal Utility District  
Mike Wirsch  
Manager, Electric Transportation  
Electric Transportation Dept., MS-30A  
6201 S Street, Box 15830  
Sacramento, CA 95852  
916-732-6754

Sacramento Municipal Utility District  
Dace Udrys  
Media & Education Services Dept.  
6201 S Street, P.O. Box 15830  
Sacramento, CA 95813  
916-732-5201

San Diego Gas & Electric  
Stephanie Donovan  
Public Relations  
8306 Century Park Court  
San Diego, CA 92123  
619-696-4285

San Diego Gas & Electric  
Howard Levine  
Manager, Alternative Vehicles  
8306 Century Park Court  
San Diego, CA 92123  
619-654-1111

Southern California Edison Company  
Diane O. Wittenberg  
Manager of Electric Transportation  
2244 Walnut Grove Avenue  
Rosemead, CA 91770

Southern California Edison Company  
Melanie Savage  
Corporate Communications Representative  
Electric Transportation Department  
GO1 - Room 418,  
2244 Walnut Grove Avenue  
Rosemead, CA 91770  
818-302-7948

## Government Agencies & Universities/Colleges

California Energy Commission  
Transportation Technology & Fuels Office  
1516 Ninth Street, MS-41  
Sacramento, CA 95814  
916-654-4634

California Energy Commission  
Bob Aldrich, Information Officer  
Media & Public Communications Office  
1516 Ninth Street, MS-29  
Sacramento, CA 95814  
916-654-4989  
E-mail: [boba@energy.ca.gov](mailto:boba@energy.ca.gov)  
Internet: <http://www.energy.ca.gov/energy/>

California Air Resources Board  
Public Information Office  
2020 L Street  
Sacramento, CA 95814  
916-322-2990  
Internet: <http://www.arb.ca.gov/>

Tommy Foltz  
Jeff Hardy  
Clean Cities  
U.S. Department of Energy  
Forrestal Building  
1000 Independence Ave., S.W.  
Washington, DC 20585  
202-

Ruth Anne Keister  
Manager  
Clean Cities Hotline  
P.O. Box 12316  
Arlington, VA 22209  
1-800-C-CITIES

Bill Fairbairn  
McClelland AFB  
Alternative Fuels Program  
5050 Dudley Blvd.  
McClellan AFB, CA 95652  
916-642-5443  
(advanced EVs)

Kathy Bearden  
Program Manager  
Mid Atlantic Regional Consortium for  
Advanced Vehicles (MARCAV)  
Concurrent Technologies Corporation  
1450 Scalp Ave.  
Johnstown, PA 15904  
814-269-2797  
E-mail: [marcav-webmaster@ctc.com](mailto:marcav-webmaster@ctc.com)  
or [bearden@ctc.com](mailto:bearden@ctc.com)

Mid-Atlantic Technology Transfer Center  
NASA Regional Technology Transfer Center  
823 William Pitt Union  
Pittsburgh, PA 15260  
412-648-7102  
E-mail: [ksmith@mtac.pitt.edu](mailto:ksmith@mtac.pitt.edu)

Linda Bluestein  
Contract Manager  
National Alternative Fuels Hotline  
(U.S. DOE-funded project)  
P.O. Box 12316  
Arlington, VA 22209  
800-423-1DOE (1363)

National Appropriate Technology  
Assistance Service (NATAS)  
P.O. Box 2525  
Butte, MT 59702  
800-428-2525

Carol Hammel  
(Dedicated EVs)  
National Renewable Energy Laboratory  
1617 Cole Blvd.  
Golden, CO 80401  
303-231-7836

Terry Penney  
(Hybrid EVs)  
National Renewable Energy Laboratory  
1617 Cole Blvd.  
Golden, CO 80401  
303-231-1756

New York State Energy Research &  
Development Authority  
Two Rockefeller Plaza  
Albany, NY 12223  
508-465-6251 ext 226

Dan Sperling  
Director  
Institute of Transportation Studies  
University of California, Davis  
Davis, CA 95616  
916-752-7434

John H. Price  
Research Associate  
Rail Transportation Program Coordinator  
University of Texas at Austin  
Center for Electromechanics  
PRC Building 133, MS R7000  
Austin, TX 78712  
512-471-4496  
E-mail: j.price@mail.utexas.edu

Dr. Joseph Beno  
Research Associate  
Electric Vehicle Program Manager  
University of Texas at Austin  
Center for Electromechanics  
PRC Building 133, MS R7000  
Austin, TX 78712  
512-471-4496  
E-mail: j.beno@mail.utexas.edu

Jeff Kahn  
U.S. Advanced Battery Consortium  
c/o Lawrence Berkeley Laboratory  
Berkeley, CA  
510-486-4019

Steven Scharf  
U.S. Department of Defense  
Advanced Research Projects Agency  
3701 N. Fairfax Dr.  
Arlington, VA 22203-1714  
703-351-8471

Ann Hegneauer  
Editor, OTT Times  
Office of Transportation Technologies  
U.S. Department of Energy  
Room 6B094, EE-30,  
Forrestal Building  
1000 Independence Ave., S.W.  
Washington, DC 20585  
202-586-8014

Kenneth Barber  
Electric & Hybrid Propulsion  
U.S. Department of Energy  
1000 Independence Avenue, S.W.  
Washington, DC 20585  
202-586-2198

Office of the Press Secretary  
U.S. Department of Energy  
Forrestal Building  
1000 Independence Ave., S.W.  
Washington, DC 20585  
202-586-5806

Richard J. King  
Office of Solar Energy Conversion  
U.S. Department of Energy  
Photovoltaic Division  
CE-131 5H-072/FOR  
1000 Independence Ave., SW  
Washington, DC 20585  
202-586-1693  
(manages solar race car competition  
between colleges/universities)

Carl Helman  
National Vehicle &  
Fuel Emissions Laboratory  
U.S. Environmental Protection Agency  
2565 Plymouth Road  
Ann Arbor, MI 48105  
313-668-4246

Tad Wyszor  
Clean Fuel Fleets Program  
U.S. Environmental Protection Agency  
2656 Plymouth Road  
Ann Arbor, MI 48105  
313-668-4332

David Gushee  
Senior Specialist, Environmental Policy  
U.S. Library of Congress  
Congressional Research Service  
Washington, DC 20540  
202-707-7228

## Groups, Organizations & Individuals

Steve McCrea  
AFC Advice  
South Florida Electric Auto Association  
1402 East Las Olas Blvd.  
Ft. Lauderdale, FL 33301  
305-463-0158  
Internet: altfuel@bcfreenet.sflin.lib.us  
(consulting, PR, marketing for AFVs)

Dr. Paul MacCready  
Chairman  
AeroVironment Inc.  
222 East Huntington Drive  
Monrovia, CA 91016  
818-357-9983  
(human-powered vehicles, designed and  
built GM SunRaycer)

E. Eugene Ecklund  
Executive Director  
Alternative Transportation Fuels Foundation  
HCR-72, Box 547-B LOW  
Locust Grove, VA 22508  
703-972-0484

Peter Baljet  
Chairman  
American Lung Association  
National Air Conservation Commission  
9350 South Dixie Highway, Ste. 1540  
Miami, FL 33153  
305-670-6774

Petrick Berry  
Secretary/Treasurer  
Australia Electric Vehicle Association Inc.  
P.O. Box 164  
Turrumurra NSW 2074  
Australia  
+61 18-40-0394 (mobile)

Cecile Martin  
Deputy Executive Director - CalETC  
Calif. Electric Transportation Coalition  
925 L Street, Suite 1490  
Sacramento, CA 95814  
916-552-7077  
Internet: CalETC@ix.netcom.com

Melissa W. Kasnitz  
CALPIRG  
California Public Interest Research Group  
1129 State Street #10b  
Santa Barbara, CA 93101  
805-564-1207  
or  
926 J Street, Suite 713  
Sacramento, CA 95814  
916-448-4516

Bill Van Amburg  
Communications Director  
CALSTART  
3601 Empire Avenue  
Burbank, CA 91505  
818-565-5606

Patrick Brown  
Center for Alternative Fuels  
B.C. Research  
Rural Route 1  
Pender Island, B.C.  
CANADA VON 2M0  
604-629-3073

Wayne Parker  
General Manager  
Clean Air Vehicle Association  
14 Piedmont Center, Suite 1205  
Atlanta, GA 30305  
404-237-1980

Coalition For Clean Air  
122 Lincoln Blvd  
Venice, CA 90291  
213-450-5192

Dr. George Gless  
Editor  
Denver Electric Vehicle Council  
2940 - 13th Street  
Boulder, CO 80304  
303-442-6566

Spencer Adler  
EcoTech Environmental Technologies  
National Capitol P.O.  
Mail Drop Box A  
Washington, DC 20013  
202-547-7313

Paul Brown  
Executive Director  
Electric Association of America  
701 Pennsylvania Ave., NW  
Washington, DC 20004  
202-508-5414

Hal & June Munro  
Electric Auto Association  
2710 St. Guiles Lane  
Mountain View, CA 94040  
510-685-7580 or 800-537-2882

Paul Heaney  
Electric Grand Prix  
6 Gateway Circle  
Rochester, NY 14624  
716-889-4415

Ellen Engleman  
Executive Director, Electricore  
723 West Michigan St., Room SL174  
Indianapolis, IN 46202-5160  
317-278-1667  
(Mid-America Electric Vehicle Consortium  
Partnering with ARPA to Promote Growth  
of Alternative Fuel Vehicles)

Electric Transit Vehicle Institute  
1617 Wilcox Boulevard  
Chattanooga, TN 37406  
615-629-1411  
or 622-2884

Electric Transportation Coalition  
1050 Thomas Jefferson N.W.,  
6th Floor  
Washington, DC 20007  
202-298-1935

Gail Hendrickson  
Electric Transportation Coalition  
701 Pennsylvania Ave., N.W.,  
4th Floor  
Washington, DC 20004  
202-508-5995

Robert Hayden  
Director  
Electric Vehicle Association of the Americas  
601 California St., Suite 502  
San Francisco, CA 94108  
415-249-2690  
E-mail: ev@evaa.org

Electric Vehicle Council of Ottawa (EVCO)  
Box 4044, Station E  
Ottawa, Ontario  
CANADA K1S 5B1

Mary Ann Chapman  
President  
Electric Vehicle Industry Association  
P.O. Box 85905  
Tucson, AZ 85754  
520-770-9885 or 520-889-0248

Engineering Society of Detroit  
2350 Green Road, Suite 190  
Ann Arbor, MI 48105  
313-995-4440  
(sponsors Enviro. Vehicle Conf. & Expo)

Margaret Morgan-Hubbard  
Executive Director  
Environmental Action  
Environmental Action Foundation  
6930 Carroll Avenue, Suite 600  
Takoma Park, MD 20912  
301-891-1100

Walter McGuire  
President  
Environmental Policy Center  
2692 Fillmore Street  
San Francisco, CA 94123-4024  
415-775-0791  
Internet: envpolicyctr@igc.apc.org

EV Media  
612 Colorado Ave., Suite 111  
Santa Monica, CA 90401  
310-394-3980  
(education and marketing tools for EV  
industry)

Lawrence Dussault  
Executive Director  
Global Electric Auto Association  
568 Braxton Place East  
Westerville, OH 43081  
614-899-6263 or 800-GLEAN-44  
FAX 899-1717

David P. Lefever  
Executive Director  
National Assn. of Fleet Administrators  
100 Wood Avenue South, Suite 310  
Iselin, NJ 08830-2716  
908-494-8100

Cathy Bergman  
National EMF Alliance  
410 West 53rd Street, Suite 402  
New York, NY 10019  
212-554-4073

Lisa Petraglia  
Northeast Sustainable Energy Association  
23 Ames Street  
Greenfield, MA 01301  
413-774-6051

Northwest Sustainable Energy Association  
50 Miles Street  
Greenfield, MA 01301  
413-774-6051  
(sponsor of American Tour de Sol)

John N. Stearns  
Coordinator  
Project California  
1201 Dove Street, Suite 680  
Newport Beach, CA 92660  
714-442-7800  
E-mail: ProjCal@CCST.org  
(state wide collaborative to push advanced  
transportation systems including fuel cell  
development, EV/ULEV demand consortium,  
Maglex/High Speed Rail, etc.)

Amory B. Lovins  
Director of Research  
Rocky Mountain Institute  
1739 Snowmass Creek Road  
Snowmass, CO 81654  
303-927-3851

Ernie Holden  
Solar & Electric Racing Association  
11811 North Tatum Blvd., Suite 3031  
Phoenix, AZ 85028  
602-953-6672

Southwest Research Institute  
6220 Culebra Road  
San Antonio, TX 78228 USA  
(hybrid and EV information source)  
• Advanced Vehicle Technology, Engine  
and Vehicle Research Division  
Ed Owens, Manager,  
210-522-2577 (eowens@swri.edu)  
Scott McBroom, Research Egr,  
210-522-3454 (smcbroom@swri.edu)  
• Emissions Research, Automotive Products  
and Emissions Division  
Ed Bass, Sr Research Egr,  
210-522-5025 (ebass@swri.edu)

Southwest Research Institute  
26100 American Drive, Suite 603  
Southfield, MI 48034  
810-353-2559

Ken Olsen & Jonny Weiss  
Instructors  
Sustainable Technologies International  
P.O. Box 1115  
Carbondale, CO 81623  
303-963-0715

Ed Begley, Jr.  
The Sterling Winters Company  
1900 Avenue of the Stars, Suite 739  
Los Angeles, CA 90067  
213-557-2700  
(actor, environmentalist and EV owner)

Tom Jaquish  
Tucson EV Association  
P.O. Box 77538  
Tucson, AZ 85705  
520-622-7856

World Solar Challenge  
(Cross-Australia Solar Car Race)  
Hans Throlstrup  
Energy Promotions  
107 Pacific Highway  
Pymble NSW 2073  
Australia  
+61 2-988-4255  
(organizer of 1996 World Solar Challenge)

## West Coast EV Clubs, Associations – MEETINGS

EAA East Bay Chapter  
Date/Time: 2nd Saturday of the month,  
10AM-Noon  
Location: Pacific Bell, 2600 Camino Ramon,  
San Ramon  
Contact: Anna Cornell, 510-685-7580  
60 Alan Drive  
Pleasant Hill, CA 94523

EAA San Francisco/Peninsula Chapter  
Date/Time: 1st Saturday, 10AM-Noon  
Location: San Bruno Library, El Camino Real  
and Angus Street, San Bruno  
Contact: Ben Compton, President, 415-221-  
3413, ext. 300

EAA Silicon Valley Chapter Meeting  
Date/Time: 3rd Saturday month, 10-12:30  
Location: Hewlett Packard, 56301 Stephens  
Creek Blvd., Santa Clara  
Contact: Lee Hemstreet, 415-493-5892  
787 Florales Drive  
Palo Alto, CA 94306

EAA North Bay Chapter Meeting  
Date/Time: 3rd Saturday of the month,  
10AM-Noon  
Location: North Bay Savings Bank, 20  
Petaluma Blvd South, Petaluma  
Contact: Jeannine Clary 707-526-7692  
(Santa Rosa)  
E-mail: gandhi!chuck@uunet.uu.net

Sacramento EV Association Meeting  
Date/Time: 2nd Saturday of the month,  
9:30AM-Noon  
Location: 6201 S Street, Sacramento, CA.  
SMUD HQ Bldg.  
Contact: Tony Cygan  
E-mail: 0002655950@mcimail.com  
Or Mark Bahlke, 916-356-6767

EAA Los Angeles Chapter Meeting  
Date/Time: 1st Saturday of the month,  
11AM-1PM  
Location: Winnett Lounge, at Hill Ave &  
Calif Ave., Cal Tech  
Institute, Pasadena.  
Contact: Irv L. Wiess, 818-841-5994  
2034 N. Brighton, Apt. C,  
Burbank, CA 91504  
or Leni Goldberg, E-mail: len@wcc.wmsnews.com

EVAOSC (Ontario, CA) Meeting  
Electric Vehicle Association of Southern  
California  
Date/Time: 3rd Saturday of the month,  
10AM-1PM  
Location: 215 E. "C" Street, Ontario, CA.  
Ontario Public Library  
Contact: Chris Martin  
E-mail: 71270.1565@compuserve.com,  
213-465-4488

EAA San Diego Chapter Meeting  
Date/Time: 4th Tuesday of the month,  
7PM-9PM  
Location: 2080 Pan American Plaza, San  
Diego Automotive Museum,  
Balboa Park, San Diego  
Contact: Ron Larrea, 619-443-3017  
9011 Los Coches Rd.  
Lakeside, CA 92040  
Jeremy Phillips (PHILLIPS@GAV.gat.com)

EAA Seattle (SEVA) Meeting  
Date/Time: 2nd Tuesday of the month, 7PM-  
9PM  
Location: 17021 1st Ave South, Verne  
Frese's basement - Call for  
directions  
Contact: Ray Nadreau (E-mail:  
rnmad@eworld.com), 206-542-5612,  
8AM-8PM  
19547 23rd N.W.  
Seattle, WA 98177

Oregon Electric Vehicle Association  
Meeting  
Date/Time: 7:30-9PM, 2nd Thursday of the  
month  
Location: On Mohawk Blvd. Energy  
Resource Center (ERC), Tualatin  
Contact: Lon Gillas, 503-434-4332  
P.O. Box 556  
McMinnville, OR 97128 USA

## EV Publications PERIODICALS

Robert Morey  
Editor  
Advanced Battery Technology  
P.O. Box 30  
Cooperstown, NY 13329  
607-547-5314

Autofacts Inc.  
The Electric Vehicle Market  
1595 Paoli Pike  
P.O. Box 2389  
West Chester, PA 19380  
215-429-9900

Backwoods Home Magazine  
Dave Duffy, Editor  
(805) 647-9341  
P.O. Box 2630  
Ventura, CA 93002 USA

Anna Crull  
Director of Publications  
Battery & EV Technology News  
10101 Fondren Road, Suite 227  
Houston, TX 77096  
713-774-39426

Clare Bell  
Managing Editor  
Current EVents  
5680 Judith Street  
San Jose, CA 95123  
408-225-6403  
Internet:cbce@delphi.com

Editor  
Electric Car  
P.O. Box 6854  
Vero Beach, FL 32961

Greg Brown  
Editor  
Electric Car Magazine  
Argus Publishers Corporation  
12100 Wilshire Blvd., Suite 250  
Los Angeles, CA 90025  
213-820-3601

Electric Grand Prix.  
Paul Heaney  
6 Gateway Circle  
Rochester, NY 14624 USA  
716-889-1229  
(Quarterly, technical & performance info.)

Electric Propulsion  
Jack Kerr, Editor  
395 Matheson Boulevard East  
Mississauga, Ontario  
Canada L4Z 2H2  
416-890-1846

Electric Vehicle Almanac  
Whiteford Press  
806 Oakwood Blvd.  
Dearborn, MI 48124  
313-274-1038  
(illustrations & specs of EVs worldwide)

I.J. Sobel  
Editor and Publisher  
Electric Vehicle Digest  
301 Scola Road  
Brookhaven, PA 1'9015  
610-872-6727  
Internet:JSobel@netxs.com

Lew Gulick  
Editor  
Electric Vehicle News and  
Global Electric Auto News  
1911 N. Fort Meyer Drive, #703  
Arlington, VA 22209  
703-276-9093  
E-mail: GLEAA@coil.com  
Internet URL: [http://  
www.smartpages.com/gleaa/  
index.html](http://www.smartpages.com/gleaa/index.html)

Paul Braus  
Editor  
Electric Vehicle Progress  
215 Park Avenue South, Suite #1301  
New York, NY 10003  
212-228-0246

Bruce Meland  
Editor  
Electrifying Times  
63600 Deschutes Market Road  
Bend, OR 97701  
541-388-1908  
E-mail: 102331.2166@compuserve.com

Environmental Energy Network  
119 South Fairfax Street  
Alexandria, VA 22314  
703-683-0774  
(FAX, magazine, online reports)

Ford Motor Company  
Leaf & Road  
AFV Newsletter  
P.O. Box 43261  
Detroit, MI 48242  
800-ALT-FUEL  
(free quarterly report on Ford AFVs)  
G.M. Electric Vehicles Progress Report  
1-800-25-ELECTRIC  
Free quarterly newsletter updating  
General Motor's EV

Ron Cogan  
Editor and Publisher  
Green Car Journal  
1334-D North Benson Ave.  
Upland, CA 91786  
909-989-0473  
(highly respected, authoritative magazine  
on Alt. Fuel Vehicles; Cogan is also  
"Autovironment" columnist for *Motor  
Trend* magazine)

Michael Coates  
Green Car Media  
17345 Grosvner Ct.  
Monte Sereno, CA 95030-2207  
408-399-9081  
E-mail: MCoates@aol.com  
(former West Coast PR person for  
Chrysler, now doing marketing for EV  
industry)

Editor  
Richard Perez  
Home Power Magazine  
P.O. Box 130  
Hornbrook, CA 96044-0130  
916-475-3179  
Bulletin Board Service: 707-822-8640  
(GIFs, graphs, diagrams)  
(energy self-sufficiency, lots on EVs -  
Magazine recently merged  
with *Alternative Transportation News*.)

Editor  
In Transit  
Runzheimer International  
Runzheimer Park  
Rochester, WI 53167  
414-767-2200

Editor  
New Fuels Report  
12225 Jefferson Davis Hwy., Suite  
1400  
Arlington, VA 22202

Paul Wilkins  
Editor  
PV Network News  
2303 Cedros Circle  
Santa Fe, NM 87505-5252  
505-473-1067

Joe Stevenson  
Editor  
Solar Mind  
759 South State, #81  
Ukiah, CA 95482  
707-463-1812

# Chapter 4

## Ethanol-Powered / Flexible Fuel Vehicles



Ethanol, ethyl alcohol or grain alcohol ( $\text{CH}_3\text{CH}_2\text{OH}$ ), is a liquid derived from corn or other grain, other agricultural products or waste. This liquid can be used as a high octane fuel in vehicles. More than four million cars run on ethanol in Brazil as a result of a government program to make fuel from sugar cane. The number of vehicles using ethanol is increasing in the United States.

Ethanol vehicle fuel is being tested in the United States in a blend called E85, 85 percent ethanol mixed with 15 percent unleaded gasoline. Farm vehicles have been converted to ethanol, as have light-duty vehicles buses and trucks, which are in testing and demonstration programs. Flexible Fuel Vehicles (FFVs) that operate on methanol and gasoline in any combination from the same tank must be calibrated to run on E85 because of the differences in energy content and other minor differences in the fuels. Most of the technical material and many of the questions and answers regarding FFVs in the chapter on methanol also relate to ethanol vehicles.

Ethanol has also been used on a large scale for many years as a gasoline blending component for energy and air quality purposes.

### History of Ethanol

The earliest forms of alcohol were simple fermented beverages. As early as 6,000 to 4,000 B.C., the art of making crude beers and wine was flourishing in the Middle East. The Chinese were probably the first to distill alcohol directly from a fermented (rice) liquor around 800 B.C. By the year 500 A.D., distillation technology had advanced to the point where relatively pure forms of alcohol were used in cosmetics, perfumes and medicines. From the 18th century to the beginning of this century, major discoveries about the chemistry and technology of distillation made it possible to produce ethanol cheaply from a variety of organic materials. In recent history, public interest in alcohol as a transportation fuel has changed with the pattern of war-prosperity-depression cycles and with the price and supply of oil.

Ethanol's history as a transportation fuel goes back many years to Henry Ford and other transportation pioneers. In the 1880s, Ford built one of his first automobiles – the quadricycle – and fueled it on ethanol. As mentioned in the opening chapter, early Ford Model Ts had a carburetor adjustment that could allow the vehicle to run on ethanol fuel that was produced by America's farmers. Ford's vision was reportedly to “build a vehicle affordable to the working family and powered by a fuel that would boost the rural farm economy.”

Rising taxes on ethanol limited its use as a fuel, and the lower cost of gasoline and a “propaganda campaign” by the oil producers kept ethanol and other alternatives from ever catching on as transportation fuels. During World War I and II in both the United States and in Europe, alcohol fuels were used as a supplement to oil-based fuels. For example, vehicle fuels were a mix of 20 percent alcohol and 80 percent gasoline in WWI. In the 1930s, research in the Midwest advocated use of alcohol in gasoline. The Nebraska legislature even passed a two-cent a gallon refund to motorists who would use alcohol blends, but the petroleum industry campaigned to cancel the plan. In WWII, alcohol was again used as a blend with gasoline. The government even commandeered whiskey distilleries into alcohol production. Following the war, oil prices dropped to ridiculously low levels, and ethanol was “out” again as a transportation fuel until the modern “gasohol” era following the 1970 oil crises.

### Modern Alcohol-Powered Vehicles

Besides early demonstration programs, the first modern, mass-produced ethanol vehicle in the United States was made by the Chevrolet Division of General Motors. A total of 50 ethanol-optimized 1992 model year Chevrolet Lumina Variable Fuel Vehicles (VFs) were demonstrated in Iowa, Indiana and other states. Chevrolet then produced 320 E85 Lumina VFs in the 1993 model year. These vehicles can operate on ethanol or gasoline in any combination from a single tank. Other auto companies are also looking at

designing fuel-flexible vehicles for E85. Ford built a limited number of E85 Taurus FFVs in 1994 model year and is planning to offer an ethanol-calibrated Taurus Flexible Fuel Vehicle in the 1995 model year for sale in the Midwest.

Ethanol-powered Flexible Fuel Vehicles produce about 30-50 percent less smog-forming emissions than a similar model gasoline-powered vehicle. Lifecycle greenhouse gas emissions for ethanol, however, may be higher because of production of the feedstock crop. According to one study by the U.S. Environmental Protection Agency, when feedstock and corn-farming practices — fuel for machinery, fertilizer and pesticide production, grain drying and fermentation — are added to a computation of carbon emissions for ethanol, total ethanol production and use emits more than six times the amount of carbon than an equivalent gallon of gasoline. Other studies dispute this claim.

Like all internal combustion engines, vehicles using ethanol emit minor amounts of aldehydes. That concern has been resolved by installation of advanced catalytic converters.

Ethanol is made from renewable resources — corn and grain feedstocks in the United States. Production of ethanol is more costly on a per gallon basis than some other alternative fuels, although government subsidies of about 54 cents per gallon (blender's credit) have kept prices comparatively low. According to trade publications, the December 1994 price for wholesale ethanol (E100) is about \$1.03 to \$1.30 a gallon (without the tax credit, the price would be \$1.57 to \$1.84 per gallon). Prices are high because of the demand for alcohol as feedstocks for oxygenates in reformulated gasoline.

Ethanol can be made from biomass — such as municipal waste and other biological waste materials. In 1992, the National Renewable Energy Laboratory estimated the potential cost of ethanol production from biomass, using its current advanced technology, at \$1.22 a gallon. That cost is expected to be lower in the future due to improvements in the technology.

The price of ethanol is also constrained because of the corn feedstock, which is closely tied to commodity prices for agricultural crops. For example, severe flooding of the Mississippi River in 1993 directly impacted the corn crop in the Mississippi basin, resulting in higher prices. This resulted in a short-term regional ethanol fuel price increase.

The use of ethanol in America has been primarily in the Midwest, where excess corn is distilled into fuel. A high percentage of Midwest service stations, especially in Iowa, offer high octane gasoline blends containing 10 percent ethanol (gasohol).

Ethanol production within California is relatively

limited. In 1991, 490 barrels of ethanol were produced per day, or a total of 20,580 gallons per day. This totaled 7.5 million gallons of ethanol a year produced within the state. Most of the ethanol feedstock is from the state's wine industry and from other liquid products, such as cheese whey.

A total of nearly 500 million gallons of gasohol (10 percent ethanol and 90 percent unleaded gasoline) were consumed in California in 1991 — this totaled 50 million gallons of neat ethanol. Gasohol use, however, dropped off dramatically in 1992 when an independent gasoline distributor (Ultramar) stopped selling gasohol, and the amount of ethanol used in the state decreased.

Ethanol consumption is expected to remain stable in California through the end of the decade. A possible increase in California production of ethanol could be realized with the construction of the Sacramento Ethanol and Power Cogeneration Plant (SEPCO). This project north-east of Sacramento combines a power plant that will make electricity for the Sacramento Municipal Utility District with a plant that will use rice straw to produce ethanol. Rice straw is currently burned in the fields at the end of harvest, but air quality restrictions will curtail that burning in a few years. The SEPCO plant is expected to produce about 12 million gallons of ethanol a year, about one-quarter of the 1991 usage in California.

Companies building plants for production of the reformulated gasoline additive methyl tertiary butyl ether (MTBE — made from methanol) are considering building swing facilities that can produce ethyl tertiary butyl ether (ETBE — made from ethanol). Both are additives that can be used in reformulated or oxygenated gasoline to reduce emissions. Ten percent ethanol blends are also being used in some areas of the country as a wintertime oxygenated blend to meet U.S. Environmental Protection Agency air pollution regulations

An ethanol vehicle has about 75 to as much as 90 percent the range of a comparable gasoline vehicle, with the same size fuel tank. This is because the energy content of ethanol is lower (75,000 British thermal units per gallon of ethanol and 105,000 Btu/gallon for E85, compared to 115,400 Btu/gallon for gasoline). Manufacturers have compensated by adding larger fuel tanks in FFVs to counteract the drop in mileage.

Because ethanol is corrosive (due to oxidation), some modifications must be made to engines and the fuel delivery system to protect parts. The cost was expected to be about the same as the FFV option for methanol — originally expected to be \$100-\$300 when full production line runs are created. Ford, however, is charging \$1,100 as the incremental cost of a 1996 Taurus ethanol FFV.

The nation's first E85 (85 percent ethanol) fueling station opened in La Habra, Orange County, California, in the spring of 1990. It is operated by the California Renewable Fuels Council, which is supporting ethanol research and demonstration programs in California.

Recently, because of the support of corn-growing states and the U.S. Departments of Energy and Agriculture, ethanol use and vehicles to use the fuel are increasing. Auto companies have responded in kind. In 1995, Chevrolet Division of General Motors announced that it would be offering up to 250,000 Chevrolet S-10 flexible fuel pickup trucks that could use ethanol.

## Questions and Answers About Ethanol

Adapted from the  
California Renewable Fuels Council

**What is ethanol and E85?** Ethanol, which is sometimes referred to as grain alcohol, is actually 200 proof **beverage** spirits. As a transportation fuel, ethanol is denatured or made unfit to drink. It is blended with unleaded regular gasoline to make E85 with 85 percent ethanol and 15 percent gasoline.

**What is ethanol made from?** Most ethanol is produced from corn or other agricultural products such as potatoes – just like whiskey or vodka are made from different products. Ethanol can be made from liquid or solid waste – such as wood by-products or agricultural waste such as rice straw. Any feedstocks that contain sugar, starch or cellulose can be fermented and distilled into ethanol.

**Is ethanol produced in California?** Yes. California producers of ethanol reclaim liquids that have historically been a waste disposal problem and process them into ethanol and other valuable co-products, such as pet food and cattle feed supplements.

**Why is ethanol defined as “RENEWABLE?”** Whether ethanol is produced from corn, rice straw or beverage waste, each of these feedstocks will be grown or produced again – therefore, ethanol is a renewable source of energy.

**What type of vehicle can operate on E85?** Fleet operators can purchase flexible fuel vehicles capable of operating on E85, gasoline or any combination of these two fuels from a single tank. The driver makes no adjustment to the vehicle, which can automatically sense the percentage of alcohol in the fuel tank and adjust the engine's parameters accordingly.

**Where can I get more information about ethanol?**  
In California, contact the:

California Renewable Fuels Council  
3304 Yorba Linda Blvd., Suite 249  
Fullerton, CA 92631  
(714) 996-6540

Additional information can be provided by the following or one of the contacts on the next page:

American Biofuels Association  
(202) 554-1026

Clean Fuels Development Coalition  
(301) 913-9636

Governor of Illinois' Ethanol Coalition  
(217) 785-2800

Iowa Corn Production Board  
(515) 225-9242

National Corn Growers Association  
(314) 275-9915

National Renewable Energy Laboratory  
(303) 231-1000

Oak Ridge National Laboratory  
Biomass Program (Energy Crops)  
(615) 574-7377

U.S. Renewable Fuels Association  
(202) 289-3835

## Current Ethanol-Powered Vehicles

<i>Vehicle Year</i>	<i>Model</i>	<i>Number Produced or Expected Production</i>
1992	Chevrolet Lumina E85 VFV	50
1993	Chevrolet Lumina E85 VFV	320
1995	Ford Taurus E85 FFV	500
1996	Ford Taurus E85 FFV	unknown
1997	Chevrolet S-10 E-85 FFV	250,000

### Ethanol Contacts

#### Automotive

(See methanol listings in next chapter.)

#### Government

Pat Fox  
Northwest Regional  
Biomass Energy Program  
Bonneville Power Administration  
905 N.E. 11th Ave.  
Portland, OR 97232  
503-230-3449

Alcohol Division  
Production Permit Information  
Bureau of Alcohol, Tobacco & Firearms  
650 Massachusetts Ave., N.W.  
Washington, DC 20226  
518-797-3377

Milton Staackmann  
Research Associate  
Hawaii Natural Energy Institute  
University of Hawaii at Manoa  
2540 Dole Street  
Honolulu, HI 96822  
808-956-2348

Noni Shawn  
National Renewable Energy Laboratory  
1617 Cole Blvd.  
Golden, CO 80401  
303-231-1947

John Cushman  
Oak Ridge National Laboratory  
Biomass Prgm.  
Short Rotation Woody Crops  
P.O. Box 20008  
Oak Ridge, TN 37831  
615-574-7377

Jack Ranney  
Oak Ridge National Laboratory  
Biomass Program – Energy Crops  
P.O. Box 20008  
Oak Ridge, TN 37831  
615-574-7377

Roger Conway  
Office Director  
U.S. Department of Agriculture  
1301 New York Ave., N.W., Room  
1208  
Washington, DC 20005  
202-219-1941

Jeff Alson  
National Vehicle & Fuel Emissions  
Laboratory  
U.S. Environmental Protection Agency  
2565 Plymouth Road  
Ann Arbor, MI 48105  
313-668-4296

#### Organizations

Bill Holmberg  
President  
American Biofuels Association  
1925 N. Lynn Street, Suite 1050  
Arlington, VA 22209  
703-522-3392

Jeff Beller and Julia Delain  
Biofuels America  
RD 1, Box 19  
Westerlo, NY 12193-9801  
518-797-3377

Cindy Hasenjager  
Regulatory Affairs Coordinator  
California Renewable Fuels Council  
3304 Yorba Linda Blvd., Suite 249  
Fullerton, CA 92631  
714-996-6540

Douglas Durante  
Clean Fuels Development Coalition  
7315 Wisconsin Avenue,  
East Tower – Suite 515  
Bethesda, MD 20814  
301-913-9636

Patricia Sullivan  
Consortium for  
Planned Biotechnology Research  
1220 Potter Drive, Suite 130-D  
West Lafayette, IN 47906  
317-494-9334

Governor's Ethanol Coalition  
ENR 325 West Adams, 3rd Floor  
Springfield, IL 62704  
217-785-2800

Iowa Corn Promotion Board  
306 West Tower  
1200 35th Street  
W. Des Moines, IA 50262  
515-225-9242

Mike Bryan  
National Corn Growers Association  
1000 Executive Parkway, Suite 105  
St. Louis, MO 63141  
314-275-9915

Eric Vaughn  
Executive Director  
Renewable Fuels Association  
One Massachusetts Ave., N.W., # 820  
Washington, DC 20001  
202-289-3835

Sustainable Farming  
REAP - Canada  
Box 125, Glenaladale House  
Ste. Anne de Bellevue, Quebec  
CANADA H9X 1C0  
514-398-7743

# Chapter 5

## Methanol-Powered / Flexible Fuel Vehicles



### Fuel and Vehicle History

Methanol (methyl alcohol), often referred to as “wood alcohol” but usually made from natural gas, is another substitute for gasoline as a transportation fuel. Its high octane and performance characteristics, the minor modifications needed to allow gasoline engines to use methanol, and the reduction of reactive emissions have made it a popular choice as an alternative fuel for fleet and private vehicle use.

According to the American Methanol Institute, methanol has been used for more than 100 years as a solvent and a chemical building block to make consumer products such as plastics, plywood and paint. It was first discovered in 1823 by condensing gases from burning wood into a liquid. Consumers use methanol directly in windshield washer fluid, gas-line antifreeze and as model airplane fuel.

Methanol is a clean-burning liquid alternative fuel. Its chemical formula is  $\text{CH}_3\text{OH}$ . A fuel-flexible vehicle using 85 percent methanol and 15 percent unleaded regular gasoline produces one-half of the smog-forming emissions than a comparable gasoline-powered vehicle.

Additionally, M85 has a 50 percent reduction in total toxic air pollutants suspected or known to cause cancer (including acetaldehyde; benzene; 1,3-butadiene), when compared to gasoline. Because methanol can be produced from abundant North American supplies of natural gas, coal or even biomass it offers energy security benefits by being a clean alternative to petroleum-based fuels.

Methanol’s power, performance and safety have also made it the fuel of choice for Indianapolis 500 race cars since 1965. A chemical derivative known as methyl tertiary butyl ether, or MTBE, is being used in new reformulated gasolines to reduce exhaust emissions.

Methanol sold for light-duty fuel-flexible vehicles is actually a blend of 85 percent methanol and 15 percent unleaded gasoline, which enhances starting ability in cold weather and safety. Known as M85, this blend is an interim step to the use of M100, or neat methanol, which offers greater air quality benefits. M85 has an octane rating of 102, compared to 92 for premium unleaded and 87 for regular unleaded

gasoline. With this higher octane is an increase in engine horsepower of about seven to ten percent, or more, depending on the vehicle.

Because it is a liquid, M85 is convenient and tanks can be filled, like with gasoline. Since, 1978, the California Energy Commission, in association with Chrysler, Ford Motor Company, General Motors, Honda, Mazda, Mercedes-Benz, Mitsubishi, Nissan, Toyota, Volkswagen and Volvo, have sponsored demonstration programs to test M85-powered vehicles in public and private fleets. Two American auto companies offered fuel-flexible vehicles for sale to fleets and the public in the 1995 model year, but only one was offering FFVs in the 1996 model year.

The Commission is working with several oil companies — ARCO, Chevron, Exxon, Mobil, Shell, Texaco, Ultramar (Beacon), and a number of independents — to continue operating the 61 methanol fueling facilities open or planned throughout California. These can supply M85 to as many as 20,000 vehicles. More would probably be added as demand increases. There are also about 50 private methanol fueling sites operated by Caltrans, public and private fleets, and school and transit districts.

### Today's Prices for Methanol

The cost of M85 increased over the last half of 1994 and into 1995 because of unforeseen occurrences in the methanol industry and the demand for methanol as a feedstock for MTBE (methyl tertiary butyl ether, an oxygenate for cleaner-burning gasoline). The price of a gallon of wholesale methanol from the California Fuel Methanol Reserve was 67 cents in December 1994, although methanol costs only about 30 cents a gallon to produce. It is selling, however, for as much as \$2.10 a gallon on the world spot market in late 1994.

That price, however, did not last long and fell in mid-1995 to about 45-cent per gallon wholesale. The spot price for methanol in March 1996 was 34-cents per gallon and was 50-cents F.O.B. at Californis storage terminals.

Added to the wholesale price of methanol are the

current federal, state and local taxes; transportation charges; cost of gasoline added to the methanol to make M85; and the dealer margins. Dealer “margins” (the charge service station dealers add to the cost of the fuel) may be as high as 20 to 25 cents a gallon (or more) because of the low volume of sales at some stations. Dealers must pay for their shipments after they’ve been received, not after they sell out a 10,000 gallon tank. Add these all together, and drivers of methanol-powered vehicles are seeing pump prices of \$0.919 to \$1.15 per gallon. This equates to a gasoline gallon equivalent price of \$1.56 to \$1.955 per gallon (based on energy content of 1.7 gallons of methanol equal to a gallon of gasoline).

The California Energy Commission estimates that methanol prices should come down as new methanol production facilities come on line and as other factors (such as addition of high margins) stabilize. Gasoline prices are also expected to go up because of the introduction of California Phase 2 reformulated gasoline, which costs more to produce. So, the prices should draw closer over time.

The forecast for methanol prices in the future is much better. The Commission forecasts the M85 price in the year 2010 will be \$1.27 for a gasoline gallon equivalent, compared to gasoline priced at \$1.48 a gallon. Diesel fuel is forecast at \$1.24 a gallon.

Because it takes about 1.7 gallons of methanol to provide the same amount of energy as a gallon of gasoline, methanol vehicles have less mileage range than their gasoline equivalents. Larger fuel tanks and the ability to use unleaded gasoline in these fuel-flexible vehicles — which run on methanol, gasoline, or any combination of the two from a single tank — provide extended range when necessary.

## Methanol Vehicles Hit the Roads

By 1996, approximately 13,000 cars, along with about 500 buses and trucks, were running on methanol in California (more than the rest of the country combined). That total is expected to increase as fuel-flexible vehicles (FFVs) and additional heavy-duty methanol-powered engines become more commonplace.

The Energy Commission has been testing alcohol-powered vehicles since 1978. But it was only in the mid-1980s when the fuel-flexible vehicle technology was created, first by Ford and followed closely behind by GM, that the number of vehicles began to increase dramatically. More than 31 million miles have been driven in California in these alcohol-powered vehicles.

It was not until the 1990s, however, that the vehicles were available for sale to fleets and the general public.

## Ford

Ford first produced a flexible fuel vehicle (FFV) in 1987 when it designed a few *Crown Victoria LTD* models to run on methanol or gasoline in any combination. Between 1987 and 1989, the company produced about 200 *Crown Victoria* FFVs which were used in various public fleet demonstration programs. In 1991, Ford produced 178 *Taurus* FFVs, and in the following year, 183 1992 Ford *Econoline* FFV vans were put into service.

In 1993, Ford produced 2,500 1993 flexible fuel *Tauruses*, 2,137 of which came to California. The *Taurus* was the first FFV to be certified by the California Air Resources Board as a Transitional Low Emission Vehicle (TLEV). The 1993 *Taurus* FFV was offered as an option from auto dealers beginning in the fall of 1992 and a number of sales were made to members of the general public.

Ford sold 2,500 *Taurus* FFVs in its 1994 model year (more than 2,200 in California) and has commitments for all of its 1995 model year FFVs (approximately 1,900). Company officials have indicated that they could produce up to 30,000 flexible fuel *Tauruses* in the 1996 model year, if there were enough orders. Orders for the 1996 model year *Taurus* FFV can be placed like a regular option, instead of ordering only during a window period.

Hertz Rent-A-Cars, a subsidiary of Ford, and other car rental companies may eventually help put FFVs in the hands of the public more than many other efforts. Following a pilot program by Avis with 20 Chevrolet *Luminas*, three auto rental car companies in Sacramento each purchased 100 Ford *Taurus* FFVs, with assistance from a Sacramento Metropolitan Air Quality Management District program. The use of FFVs in rental fleets was a resounding success and the companies purchased additional FFVs in 1994.

Hertz announced in November 1994 that it was purchasing 400 1995 *Taurus* FFVs for use at its airport rental fleets in the Los Angeles area. The company is also installing methanol refueling tanks and dispensers at four airport locations to fuel the vehicles with M85. Hertz officials say they would like to buy as many as 3,000 *Taurus* FFVs a year in California, if Ford would make them. Many of these cars would then be available for purchase by the public or other fleets following their six-month rental lifespan.

Ford charged an extra \$500 incremental cost for a *Taurus* FFV in 1995 model year. It gave a rebate of

the same amount to buyers, making the vehicle the same price as gasoline-only. Ford is charging an additional \$1,200 for 1996 model year *Taurus* FFVs but is offering a comparable manufacturer's rebate, so there is not additional cost.

## General Motors

Following a test fleet of 20 Chevrolet *Corsicas* in 1988 and 212 1991 model year Chevrolet *Luminas* in 1991, in November 1991, General Motors and the Energy Commission announced the availability of Chevrolet Variable Fuel Vehicle (VFV) *Luminas* for purchase by public and private fleets as well as members of the general public. A total of about 1,200 *Luminas* were sold to California fleets in early 1992. Chevrolet again offered the VFV option with the 1993 model year *Luminas*.

Because of a major body redesign of the *Lumina*, VFVs were not offered in the 1994 and 1995 model years. Chevrolet then announced it could produce up to 250,000 *S-10* flexible fuel pickup trucks in the 1997 model year capable of running on ethanol, but the auto company **will not** offer *S-10s* FFVs that can run on methanol. The company has also not talked about plans for future methanol-powered vehicles.

## Chrysler

At the 1991 Greater Los Angeles Auto Show, Chrysler announced that it would build 2,500 1992 model year, "A-body" cars (Plymouth *Acclaims* and Dodge *Spirits*) to run on methanol. The flexible fuel vehicles were offered for sale in California to fleets and the public. The flexible fuel /methanol option was offered to the purchaser at no extra cost. With government incentives, this made the Chrysler FFV less expensive than a gasoline-only model. The other auto companies followed suit, charging nothing extra for the FFV option. They later reinstated charging for the incremental cost.

Chrysler later announced that nearly all of the 910 1993 model year *Acclaims* and *Spirits* were purchased by the United States General Services Administration, out of a total of 1,119 that came to California. All Chrysler Spirit/*Acclaims* FFVs were certified as Transitional Low Emission Vehicles by the California Air Resources Board.

In the 1994 model year, Chrysler again sold nearly all of its *Acclaims* and *Spirits* to the U.S. GSA. Chrysler's 1994 LH series (Chrysler *Concord*, Dodge *Intrepid* and Eagle *Vision*), were offered with the methanol option. Because it was not certified by the California Air

Resources Board, however, the flexible fuel LH was not offered in California in 1994, except for a few experimental models.

Chrysler again offered its Dodge *Intrepid* FFV in the 1995 model year, ARB-certified as TLEV. The company may consider offering the flexible fuel option on the *Stratus* or *Cirrus* models, which replaced the *Acclaim* and *Spirit* in Chrysler's line up. The company, however, has made no announcement of its future intentions for FFVs and is not offering an FFV in 1996.

## Foreign Auto Companies

Foreign auto companies are also working on fuel-flexible vehicles. Volkswagen has produced more than 50 fuel-flexible *Jettas* in the early 1990s. Honda, Mazda, Mercedes-Benz, Mitsubishi, Nissan, Toyota and Volvo have all produced a limited number of demonstration or experimental vehicles. It is unknown what marketing plans, if any, that foreign car companies have for their flexible fuel vehicles.

## Questions and Answers About M85 and Flexible Fuel Vehicles

### Questions About the Vehicles

**What is a fuel-flexible vehicle? Do you have to switch between methanol and gasoline? Are they in separate tanks?** A fuel-flexible vehicle is specially designed by an auto manufacturer to use methanol or regular unleaded gasoline in any combination from a single tank. The vehicles have a special sensor on the fuel line that can detect the ratio of methanol to gasoline that is in the tank. The sensors tell on-board computers about the fuel mixture, and the computer automatically adjusts the vehicle's fuel injection and ignition timing to compensate for the different fuel mixtures.

**What happens when methanol is not available?** The fuel-flexible option allows the driver to use any combination of gasoline or methanol — from 100 percent unleaded gasoline to 85 percent methanol. A driver can therefore use unleaded gasoline if methanol is not available.

**What are the differences in a fuel-flexible vehicle compared to a regular gasoline-powered model? Are different parts used?** There is only one major additional part that is included on a fuel-flexible vehicle — the fuel sensor that detects the methanol/gasoline ratio. A number of other parts on the fuel-flexible vehicle's fuel-delivery system need to be changed to handle methanol: fuel tank, fuel lines, fuel injectors, computer system, anti-syphon device and dashboard gauges are different. Alcohol is corrosive, especially to rubber and plastic parts. Hence parts that are tolerant to alcohol fuels must be substituted on the auto manufacturers' assembly line for parts that will come in contact with the alcohol fuel.

**Is the trunk space of the car affected by using methanol?** Unlike compressed natural gas or propane, no additional fuel tank is needed for methanol. Because a fuel-flexible vehicle is fueled just like a gasoline vehicle and has only one tank, trunk space is not compromised.

**What is range of fuel-flexible vehicles? Is the mileage lower for fuel-flexible vehicles?** Methanol has about half the energy content of gasoline. With current engine technology, a vehicle needs about 1.7 gallons of methanol to go the same distance one gallon of gasoline will take the vehicle. The range of a fuel-flexible vehicle is dependent on the tank size and driver fuel efficiency techniques. The distance a fuel-flexible vehicle can go depends on a number of factors. Some auto manufacturers will be increasing the fuel tank size in their fuel-flexible vehicles. Ford Motor Company is equipping its newer fuel-flexible vehicles with a 20 gallon fuel tank instead of a 16 gallon tank. Vehicles tested have a range of 200 to 400 miles depending on tank size.

**What is the price of the fuel-flexible option on a vehicle?** When the cars are mass-produced, the estimated cost for the fuel-flexible option is about \$250 per vehicle or less. Chevrolet, Chrysler and Ford, however, have offered the methanol option at no additional cost to the consumer. That did change, however, with Ford increasing the additional cost to \$450 in 1995 and \$1,200 in 1996.

**Do FFVs qualify for a federal or state tax credit or deduction?** If there is no incremental (additional) cost to allow the FFV to run on alcohol fuel, above the price of a comparable gasoline model, then the vehicle does not qualify for a credit or deduction.

**Can a car be retrofitted to use methanol?** Yes. A car can be retrofitted, but there may be no air-quality

or emissions benefits from doing so, and there are no methanol conversion kits certified by the California Air Resources Board. So, even though a car could actually be converted, it is not practical to do so and may not meet emission regulations. Fuel-flexible vehicles are specially suited to burning methanol as efficiently as possible and run cleaner than using gasoline. Switching a regular car to methanol would require special adjustments to or changes in the vehicle's computerized fuel injection system. This could not be done by the average person but may not be out of the question for qualified converters.

**Are the vehicles covered by factory warranties?** The fuel-flexible vehicles are completely covered by the original equipment (auto company) manufacturers' factory warranties. Some auto companies even offer extended warranties. Ford's 1993 *Taurus*, for example, had a six year /60,000 mile warranty. Methanol equipment is often given a lifetime warranty.

**Are repairs and maintenance costs for fuel-flexible vehicles any different?** No. The costs are roughly the same as regular auto repairs and maintenance. A fuel-flexible vehicle does run cleaner, so some maintenance costs may actually be reduced in the long run.

**Is a special oil needed for the vehicle? Does it cost more?** A special lubricant additive with enhanced acid-neutralizing capabilities is used in current models. Oil changes are recommended every 3,000 to 6,000 miles, depending on model. Because this special oil is produced in limited quantities, it can be more expensive than regular oil. The Energy Commission has been working with auto makers to price the oil at a reasonable cost.

## Questions About the Fuel

**What is methanol?** Methanol is methyl alcohol, commonly known as "wood alcohol." It is a colorless, flammable liquid, with the chemical formula  $\text{CH}_3\text{OH}$ . For more than 100 years, methanol has been used as a solvent and chemical building block to make consumer products such as plastics, plywood and paint. Its primary market is formaldehyde urea glue used in building products. It is also used as a gas line antifreeze, model airplane fuel, in windshield washer liquid, general solvent, as a racing fuel, and as a feedstock in the petrochemical industry.

Methanol is mandated as the only fuel that is used on the Indy Car racing circuit. Back in 1964, the Indianapolis 500 race suffered a horrendous pile-up of cars and resulting gasoline fire and deaths. That was

the last time gasoline was used to power a vehicle at an Indy-type race.

Professional Indy driver Scott Brayton (quoted in the Canadian Oxygenated Fuels Association's Methanol News) says: "Methanol has been the preferred racing fuel for (three) decades. It is one of the cleanest-burning fuels, with a high flash point. In the event of an accident, a methanol fire can be extinguished with water...while water on gasoline spreads the fire. Methanol provides a racing car with high performance, while acting as a coolant. It helps us get those jack rabbit starts — acceleration from zero to 100 miles per hour in under three seconds."

**How is methanol produced?** Methanol can be produced from just about anything containing carbon, including natural gas, coal or biomass. Currently, abundant North American supplies of natural gas are used as the feedstock source of methanol. Typically, methanol is produced using steam and pressure, and a catalyst that converts natural gas, or methane, into the liquid methanol. Methane gas (a greenhouse gas) given off by decomposing vegetable matter in landfills may also be tapped as a source for methanol production. A research and demonstration project in Southern California funded by the Energy Commission and the South Coast Air Quality Management District will use biomass to produce methanol in what is known as the Hynol process.

**What fuel is used in the fuel-flexible vehicles?** M85 is the fuel available at designated retail outlets to use in FFVs. M85 is a mixture of 85 percent methanol and 15 percent regular unleaded gasoline. The gasoline is added to provide color to a flame, should there be a fire involving M85, and to assist in vehicle-starting during colder weather. The gasoline also adds a smell and color to the clear, odorless methanol to prevent possible misuse.

**Does M85 have lower exhaust emissions when compared to gasoline?** Vehicles using M85 produce 30 percent to 50 percent less of the smog-forming emissions than regular unleaded gasoline used in a comparable vehicle. Emissions of nitrogen oxides and hydrocarbons are usually less than gasoline; but emissions of carbon monoxide are sometimes lower but usually equal or slightly higher. Reformulated gasoline is expected to be about 30 percent cleaner than today's gasoline, so "reformulated M85" (85 percent methanol and 15 percent reformulated gasoline) should have even lower levels of smog-forming exhaust emissions.

**How does M85's octane rating compare to gasoline?** M85 is a high-performance liquid fuel with a pump octane rating of 102, compared to 92 octane for premium unleaded gasoline and 87 for regular unleaded gasoline.

**Is there an increase in vehicle performance with M85?** Using methanol in a fuel-flexible vehicle increases the horsepower by about 7-10 percent, or more, depending on the vehicle.

**Is M85 more toxic or dangerous than gasoline?** All motor vehicle fuels are toxic or dangerous, so methanol should be considered as toxic. The same precautions used with gasoline must be taken when using M85. M85, like gasoline, should not be ingested as it can be fatal, and persons should not siphon methanol from a tank. If M85 is splashed on the skin, it should be washed off immediately. Clothing should be changed and laundered as soon as possible if M85 is spilled on them.

On the plus side, pure 100 percent methanol contains none of the carcinogenic "ingredients" of gasoline like benzene, 1,3 butadiene and acetaldehyde. M85 (with 15 percent unleaded gasoline) contains a lesser amount of these carcinogens. The EPA says methanol is not a carcinogen, reproductive or mutagenic hazard, and not a threat to a fetus.

**What about formaldehyde?** All internal combustion engine vehicles today emit some amount of formaldehyde. With new catalytic converter technology, the amount of formaldehyde emitted by a fuel-flexible vehicle is reduced dramatically. Research by Carnegie Mellon University indicates that formaldehyde emissions can be kept in check by catalytic converter technology. The California Air Resources Board has established a formaldehyde emissions standard for all motor vehicles. The FFVs sold in California meet ARB's stringent standard for formaldehyde.

**If M85 is spilled on the ground, can it contaminate ground water?** Methanol is water-soluble and, as such, could be quickly diluted in large bodies of water to levels which are safe for organisms. M85 spills should not lead to environmental effects worse than petroleum fuels, and in many cases the recovery rates are faster. While the behavior of M85 spills continues to be a valid research topic, it is more important to determine cleanup procedures for M85 or M100 methanol spills. Current regulations for underground fuel storage tanks require that the tanks be double-walled. The likelihood of an undetected leak of M85 or any other fuel

occurring from these tanks is extremely small.

**Is there a fire hazard with M85?** M85 like any other fuel is flammable. According to the U.S. Environmental Protection Agency, compared with gasoline, M85 results in much lower frequency of vehicle-related fires and a lower hazard to people and property, should a fire occur. M85 is more difficult to ignite than gasoline because of its high flash point, and if ignited, M85 burns in a more controlled manner with less heat than other transportation fuels.

**What is the difference between M85 and Gasohol?** Gasohol is a blend of unleaded gasoline and 10 percent ethanol — ethyl or “grain” alcohol. M85 is a blend of 85 percent methanol and 15 percent unleaded gasoline.

**Will I hurt a regular gasoline vehicle if I use M85?** Yes. Vehicles not specially outfitted to use methanol can be damaged. A gasoline vehicle simply won't run on a high percentage of methanol. When using a lower percentage of methanol, damage is usually to parts susceptible to corrosion — rubber and plastic hoses, etc. Gasoline vehicles using even a small amount of methanol may be rendered inoperable.

**What mileage can you get with M85?** It takes about 1.64 to 1.7 gallons of M85 to equal a gallon of gasoline, depending on the vehicle. A mid-size car with a 16 gallon tank can travel 424 highway miles on gasoline and 249-258 miles on methanol (based on 26.5 m.p.g. on gasoline).

**What is the price of M85?**

The price of 100 percent methanol through the California Fuel Methanol Reserve in March 1996 was 54 cents per gallon. M85 costs between \$0.919 and \$1.20 cents per gallon retail (depending on the retail outlet selling M85). The additional cost includes transportation charges, the cost of the 15 percent unleaded gasoline when the product was delivered, dealer margin or profit (normally 10% of wholesale price but can be up to 20 to 25 cents per gallon – or more) and taxes. Because it takes 1.7 gallons of M85 to equal a gallon of gasoline, this works out to \$1.567 to \$2.04 cents per “gallon equivalent.”

## Questions About Methanol and the California Methanol Fuel Reserve

**Where does California get its methanol for the fuel demonstration program?** Since the program's creation, methanol has been produced for California's

demonstration program from natural gas in Canada and the U.S. Gulf Coast. It was supplied by a number of companies including: Beaumont Methanol Corporation, Enron Petrochemicals Company, Hoescht Celanese Chemical Group, Intermountain Chemical Inc., Methanex Corporation and Novacor Chemical USA. Methanex holds the current contract in California to supply an annual total of 21 million gallons of methanol for the state's fuel methanol reserve. The company delivers the methanol to storage areas in Northern and Southern California. From these areas it is mixed with unleaded regular gasoline and transported to retail network participants.

**Who sells M85?** Under 10-year agreements with the Energy Commission, ARCO, Chevron, Exxon, Mobil, Shell, Texaco, Ultramar (Beacon), and a number of independents have agreed to participate in the Methanol Retail Fuel Supply Network. (See Chapter 10 for locations.) Other oil companies have expressed an interest in retailing methanol. The oil companies install, operate and maintain the M85 equipment at their stations throughout California. The Energy Commission supplies the methanol fuel storage and dispensing equipment. A number of private companies and government agencies have their own private methanol fueling facilities.

**Where can M85 be purchased?** In March 1996, M85 could be purchased at 54 retail service stations, with another seven stations due to open by September. Many of these sites are in Southern California. Additional stations could be added as the number of vehicles needing M85 increases. There are also about 50 private methanol fueling facilities that are not open to the public.

**Are these regular service stations?** Yes. Because of the need to expand the public availability of M85, the Energy Commission encourages that M85 usually be sold by stations owned and operated by an oil company. There are also private methanol fueling stations at various light-duty fleet yards, transit agencies and at school districts using methanol-powered buses, but these are not open to the public.

**Where are these stations located?** The stations are located in close proximity to fleets operating fuel-flexible vehicles. Usually about 30 to 50 fuel-flexible vehicles are needed in any given area to justify a fueling location. Most of these stations are strategically located along well-traveled thoroughfares such as interstates or freeways. Under an agreement with Caltrans, logo signs displaying a fuel dispenser with a letter “M” on

it and the word “Methanol” are located along freeways and surface streets to direct motorists to the methanol station. In addition, the Energy Commission publishes a Methanol Fueling Guide, a small loose-leaf binder with maps locating all M85 fueling stations in California. This binder is updated regularly.

**Does a service station need a special M85 tank below ground?** Because the fuel is “corrosive” to rubber, some metals and certain plastics, special methanol-compatible storage facilities, tanks, hoses, pumps and parts are needed. It is estimated that more than 800-900 tanks at service stations in California are methanol tolerant. Some local air quality districts require that newly installed double-walled tanks and equipment are methanol-compatible.

**What is the cost of installing M85 fueling equipment? Can one be installed for a public or private fleet?** The cost for dispensing equipment is roughly \$35,000 at oil company owned and operated facilities. An in-ground tank can cost about another \$45,000. Private fleets may put in their own methanol fueling facility, and the Energy Commission offers help with design plans and equipment specifications. Private facilities, however, must provide documentation of maintaining M85 purity. If a below-ground tank is already methanol-compatible, the cost for installing the equipment is substantially less.

**How is the fuel system accessed?** Currently, the M85 pumps are equipped with credit card, ATM-style

electronic readers maintained and billed by Chevron. The Card is similar to an electronic automated teller banking card but is good only for dispensing methanol. This prevents improper fueling of gasoline vehicles with methanol. Chevron bills the fleets directly for the methanol dispensed, provides a written print out of vehicle fuel usage, including mileage to help compute miles-per-gallon, and then pays each oil company directly. This rids a fleet owner of having to deal with separate oil company credit cards and allows one single monthly payment, no matter which oil company the M85 is purchased from. In the future, oil companies will probably offer M85 through their own credit card systems, so a Visa or Mastercard could be used. Research is also underway to develop a different filler nozzle for methanol pumps that cannot be used in regular gasoline-only vehicles (similar to the leaded gasoline nozzles that could not be used in unleaded gasoline-fueled vehicles) to prevent misfueling. With this special nozzle, a card system will not be needed to prevent misfueling.

**How do I contact Chevron for the special card?**  
Please contact Chevron at:

California Fuel Methanol Reserve  
Card-Key Access  
Judy Burns  
Chevron Products Company U.S.A.  
P.O. Box 9560  
Concord, CA 94524-9875  
800-554-1376

## Methanol Vehicles in California

### Previous Methanol & Flexible Fuel Vehicles Sold

1982-1987 Ford Escort “dedicated” methanol vehicle .....	500
1987-1989 Ford Crown Victoria LTD FFV .....	218
1988 Chevrolet Corsica VFV .....	20
1991 Chevrolet Lumina VFV .....	212
1991 Taurus FFV .....	178
1991 Volkswagen Jettas .....	50
1992 Chevrolet Lumina VFV .....	1,192
1992 Chevrolet Lumina VFV (E85*) .....	50
1992 Chrysler Spirit/Acclaim FFV .....	700
1992 Ford Econoline Van FFV .....	183
1993 Chevrolet Lumina VFV .....	75
1993 Chevrolet Lumina VFV (E85*) .....	320
1993 Chrysler Spirit/Acclaim FFV .....	1,119
1993 Ford Taurus FFV .....	2,137
1994 Ford Taurus FFV .....	2,257
1994 Chrysler Spirit/Acclaim FFV .....	1,690
1994 Dodge Intrepid FFV .....	(limited number produced)
1995 Ford Taurus FFV .....	1,940
1995 Dodge Intrepid FFV .....	300

\* Vehicles sold in Midwest for demonstration fleets using Ethanol.

### Currently Available Methanol-Powered FFVs

1996 Ford Taurus M85 FFV

Note: Some 1994 and 1995 models may be available as used vehicles from car rental company resale outlets.

## Methanol-Powered Flexible Fuel Vehicle Contacts

### Auto Makers

A. Michel Clement  
Alternative Fuels Vehicle Marketing  
Chrysler Corporation  
12000 Chrysler Drive  
CIMS 414-03-44  
Highland Park, MI 48288  
313-956-4599

Lou Ulrich  
Account Executive  
Fleet Sales Dept.  
General Fleet Office  
Ford Division  
2099 South State College Blvd.  
Suite 600  
Anaheim, CA 92816  
714-939-3562

W.J. "Bill" Boultas  
Account Executive  
Fleet Sales Dept.  
General Fleet Office  
Ford Division  
P.O. Box 9048  
Pleasanton, CA 94566  
510-463-5791

Ford Motor Company  
Alternative Fuel Vehicle Hotline  
1-800-ALT-FUEL (258-3835)

Gerald J. Barnes  
Manager  
Automotive Emissions Control  
General Motors Corporation  
3044 West Grand Blvd.  
Detroit, MI 48202  
313-556-7723

### Fuel Providers

Ray Lewis  
Executive Director  
American Methanol Institute  
815 Connecticut Ave., N.W.,  
Suite 800  
Washington, DC 20006  
202-467-5050

Kenneth D. Smith, Consultant  
(West Coast Representative)  
American Methanol Institute  
3939 Fair Hill Rd.  
Fair Oaks, CA 95628  
916-204-4421

California Fuel Methanol Reserve  
Card-Key Access  
Judy Burns  
Chevron Products Company U.S.A.  
P.O. Box 9560  
Concord, CA 94524-9875  
800-554-1376

### Government Agencies

California Energy Commission  
Transportation Technology & Fuels Office  
1516 Ninth Street, MS-41  
Sacramento, CA 95814  
916-654-4634

Ruth Anne Keister  
Clean Cities Hotline  
P.O. Box 12316  
Arlington, VA 22209  
1-800-C-CITIES  
703-528-1953

Linda Bluestein  
Contract Manager  
National Alternative Fuels Hotline  
P.O. Box 12316  
Arlington, VA 22209  
800-423-1DOE (1363)  
703-528-1953

National Appropriate Technology  
Assistance Service (NATAS)  
P.O. Box 2525  
Butte, MT 59702  
800-428-2525

New York State Energy Research &  
Development Authority  
Two Rockefeller Plaza  
Albany, NY 12223  
508-465-6251 ext 226

Jeff Alson  
National Vehicle  
& Fuel Emissions Laboratory  
U.S. Environmental Protection Agency  
2565 Plymouth Road  
Ann Arbor, MI 48105  
313-668-4296

Tad Wysor  
Clean Fuel Fleets Program  
U.S. Environmental Protection Agency  
2656 Plymouth Road  
Ann Arbor, MI 48105  
313-668-4332

David Gushee  
Senior Specialist, Environmental Policy  
U.S. Library of Congress  
Congressional Research Service  
Washington, DC 20540  
202-707-7228

## Organizations

E. Eugene Ecklund  
Executive Director  
Alternative Transportation Fuels  
Foundation  
HCR-72, Box 547-B LOW  
Locust Grove, VA 22508  
703-972-0484

Michael McNeil  
Canadian Oxygenated Fuels  
Association  
190 Bronson Ave.  
Ottawa, CANADA K1R 6H4  
613-232-9729

Wayne Parker  
General Manager  
Clean Air Vehicle Association  
14 Piedmont Center, Suite 1205  
Atlanta, GA 30305  
404-237-1980

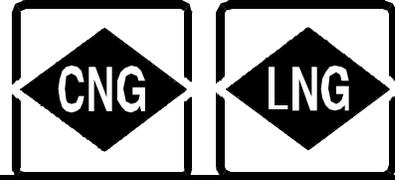
David P. Lefever  
Executive Director  
National Assn. of Fleet Administrators  
100 Wood Avenue South, Suite 310  
Islelin, NJ 08830-2716  
908-494-8100

L. Donald Shields  
Coordinator, Project California  
California Council  
on Science & Technology  
100 Academy Drive  
Irvine, CA 92715  
714-854-4150



# Chapter 6

## Natural Gas Vehicles



### Fuel and Vehicle History and Characteristics

Of all the liquid or gaseous fuels ready for commercial transportation use, compressed natural gas (CNG) and liquefied natural gas (LNG) offer the largest reductions in emissions compared to gasoline: carbon monoxide is reduced by 65 to 90 percent, particulates are virtually eliminated, and the ozone reactivity from natural gas vehicles is up to 80 to 90 percent better than gasoline emissions.

A practical gas engine was developed and built by Etienne Lenoir of France in 1860 that ran on illuminating gas from coal. The gas was stored in a rubber bladder. In 1862, he built a vehicle powered by one of his engines.

The natural gas vehicles today have come a long way. CNG is being used in California in light-duty passenger vehicles and pickup trucks, medium-duty delivery trucks, and in transit and school buses. LNG is being looked at favorably for heavy-duty applications, such as transit buses, and other transportation applications, such as locomotives and long-haul semi-trucks. The California Energy Commission is working with local governments and natural gas utility companies to demonstrate various vehicles in daily applications and to help commercialize this clean fuel.

Natural gas vehicles are expected to help auto companies meet the state Air Resources Board mandates for Low Emission Vehicles and Ultra-Low Emission Vehicles, which take effect in 1997. And because there are abundant North American supplies of natural gas, use of CNG to replace gasoline will help reduce the country's dependency on petroleum.

Natural gas vehicles (NGVs) are more common abroad. Italy has about 300,000 natural gas-powered vehicles; the former Soviet Union has an estimated 250,000; New Zealand has more than 150,000; Australia has some 75,000; and Canada has more than 20,000. According to the American Gas Association, there are an estimated 35,000 NGVs operating in the United States. By the end of May 1992, there were more than 800 NGVs in utility company and other

fleets in California. By May 1994, the natural gas utility companies estimate that this number jumped to about 3,500. By June 1995, that number increased to 5,712 NGVs and a total of 10,243 were expected at the end of 1995.

The cost of equipping a light-duty vehicle to run on compressed natural gas can range from about \$4,000 up to about \$6,000, depending on the vehicle and number of cylinders to store the fuel. California and the federal government offer various incentives for natural gas vehicles to help reduce this cost. During 1994, the Energy Commission offers a limited amount of fund toward \$1,000 "rebates" for a vehicle that is certified by the Air Resources Board as a Low Emission Vehicle. The Commission offers a \$1,500 "rebates" for an Ultra-Low Emission Vehicle. These "rebates" are available directly from the state's three main natural gas utility companies — Pacific Gas and Electric, Southern California Gas, and San Diego Gas & Electric.

CNG ranks relatively high in convenience and availability. California's extensive network of natural gas pipelines can deliver the fuel directly to many sites where compressors are installed by the local utility, including individual homes. Two types of fueling systems are available for commercial use: a "quick fill" system that fuels a vehicles in five minutes (similar in time to fueling a vehicle with gasoline), or a "slow fill" system that can fuel an entire fleet overnight. CNG may be the preferred clean, alternative fuel for fleet use where vehicles travel specified routes, such as delivery trucks, and return to a central yard where they can be slow-filled overnight.

Costs for a "slow fill" system or "quick fill" system to handle public or private fleets can cost \$250,000 or as much as \$3 million for a bus fleet. A compressor station typically costs \$2,000 to \$4,000 per vehicle served. Refueling can be done easily by trained drivers. Costs for a compressor for use with a single vehicle in private homes averages about \$3,500. Individual home compressors use a slow-fill system for overnight refueling. The small compressor would usually be located in a home's garage area and would be connected directly to the natural gas supply in the house.

As of June 1995, there were 131 public and private natural gas vehicle fueling facilities in California, 85 of which are open for public use. An additional 21 public and 23 private stations were added by the end of 1995. As natural gas usage increases, new stations will be added by tapping into the existing municipal natural gas main system. Chevron, Shell, Texaco and Unocal have entered into agreements with natural gas utility companies to dispense CNG at various gasoline stations. Some private companies are also selling CNG, including FleetStar and MESA.

Automobile manufacturers are developing dedicated CNG engines that are extremely clean, which should lower capital vehicle costs and create further improvements in efficiency. Conversions of gasoline-powered vehicles to CNG are also possible with kits certified by the California Air Resources Board (see list below of certified vehicles). Conversion of vehicles also creates jobs for local economies and vocational education opportunities for high schools and community colleges.

CNG's biggest drawback remains its reduced range of 120-180 miles for the average vehicle with three cylinders. Newer technology vehicles have been recently demonstrated, however, that reportedly have a range of up to 300 miles, such as the CNG Honda Civic now being tested in the state. Bi-fuel vehicles that can operate on gasoline or natural gas at the flick of a switch, or use an automatic switching system, are available when extended range is necessary — though bi-fuel vehicles may have higher average emissions than dedicated natural gas vehicles. Advanced designs optimized for CNG are expected to routinely provide ranges of 300 miles or more for passenger cars.

Also, because of the gaseous nature of the fuel, the time of day and the ambient air temperature can affect the amount of fuel that can be compressed into a tank. For example, if drivers filled the cylinders on a hot afternoon, drove home and parked overnight; they would find the cylinder not totally full in the cool of the morning. The heat would have expanded the gaseous fuel during the hot afternoon so that the cylinder registered only 75 to 85 percent full in the morning. CNG retailers are working to correct this situation.

## Questions and Answers About Natural Gas Vehicles (NGVs)

**What is a Natural Gas Vehicle? Can you switch between natural gas and gasoline?** A Natural Gas Vehicle (NGV) is a vehicle that operates on compressed (CNG) or liquefied natural gas (LNG) in a vehicle dedicated to run only on that fuel, or one that operates on both natural gas and gasoline (called a dual-fuel or bi-fuel vehicle). Bi-fuel vehicles usually have a switch located on the dash that lets the operator choose between the two fuels. Some bi-fuel vehicles have an electronic switch that will automatically change from natural gas to gasoline, but only when the natural gas is nearly depleted.

**What happens when compressed natural gas (CNG) is not available?** A dedicated CNG vehicle must be able to reach a refueling facility to refuel. With a bi-fuel vehicle, if CNG cannot be accessed, then regular gasoline may be used by switching the vehicle over.

**What are the differences between an NGV and a regular gasoline-powered model? Are different parts used?** The primary difference is in the fuel storage and intake system. Natural gas vehicles hold the gas in high pressure cylinders. From here, the gas travels along a high pressure fuel line leading to the engine compartment. With bi-fuel vehicles, the CNG tanks and lines are in addition to the conventional gasoline components.

**Is the cargo space of the vehicle affected by using CNG?** On dedicated vehicles the trunk space is only slightly affected, if at all. The cylinders are usually secured to the bottom of the vehicle to avoid any inconvenience they may cause. On bi-fuel vehicles, the gasoline tank is left in place. Because of this, trunk or cargo space is usually reduced because of the additional room required for the cylinders.

**What is the range of a natural gas vehicle (NGV)?** Range depends on cylinder volume, engine size and driving habits. On average, a current model NGV can achieve a range of 120-180 miles. That range was recently extended in special Geo Prizm and Honda Civic prototypes that reportedly can go 300 miles. The Prizm did so while retaining 80 percent of its cargo/trunk capacity.

**Is the mileage lower for NGVs? What mileage can be achieved with CNG?** Beginning January 1, 1995, CNG will be sold in California in units that are the equivalent of a gallon of gasoline, rather than in therms of CNG (which have slightly less energy content than a gallon of gasoline). Hence the mileage of a "gasoline gallon equivalent" with a properly adjusted NGV should be roughly the same as conventional gasoline vehicle. Mileage on a bi-fuel NGV will probably be slightly lower than a conventional gasoline-only vehicle. On a dedicated NGV mileage may even increase because the vehicle's compression ratio is changed to take advantage of natural gas' 130 octane rating.

**What automobile/engine manufacturers are participating in the production of NGVs?** GMC/Chevrolet, Chrysler and Ford have all produced NGVs. Several heavy-duty vehicle engine manufacturers have built engines to use CNG for buses, trucks and other heavy-duty vehicles. Some foreign car companies are also working on natural gas-powered vehicles. (See list below.)

**What NGVs are available to be purchased?** American automobile manufacturers have natural gas vehicles on the market and ready for sale. Please see below for list of vehicles. (See attached list.)

**How many NGVs are there in California and elsewhere?** As of December 1995, there were more than 5,700 NGVs on California's streets and highways. Nationally, there are an estimated 50,000 NGVs. NGVs are more common abroad. Italy has about 350,000 NGVs; the Soviet Union has an estimated 250,000; New Zealand 150,000; Australia has some 75,000, and Canada has more than 20,000.

**What will be the price of the CNG option on a vehicle?** Chrysler charges about \$4,000 more for a natural gas vehicle than a gasoline-only model. GMC charged approximately \$3,700 more than a gasoline vehicle, but these figures may vary depending on vehicle and number of fuel cylinders. Original Equipment Manufacturers are working with the natural gas industry to reduce the differential cost to only \$2,000 within three years by exploring CNG-optimized designs.

**Can a vehicle be retrofitted to use CNG?** Yes. The natural gas utility companies all have programs to assist fleet operators and individuals in conversion of gasoline vehicles to CNG. Conversion kits must be certified by the California Air Resources Board, which requires emission warranties equivalent to those provided by

Original Equipment Manufacturers. Both the Air Resources Board and the California Bureau of Automotive Repair maintain lists of certified conversion kits and companies that do conversion work.

**How much does it cost to retrofit a vehicle to use CNG?** The cost to have a vehicle converted is between \$1,500 to \$4,000. Some disadvantages are that emissions may not be as low and there may be a slight power loss because the engine wasn't originally designed to run on CNG.

**Are the vehicles covered by factory warranties?** All vehicles produced by an Original Equipment Manufacturer (OEM) to run on natural gas have a full coverage warranty, same as a gasoline-powered vehicle. Vehicles that are converted after market to use CNG, may or may not be covered by the OEM warranty. The California Air Resources Board, however, requires that the retrofit component manufacturers fully warrant their products. A consumer should check with their vehicle's manufacturer about warranties before converting.

**Are repair and maintenance costs for NGVs any different than gasoline vehicles?** Although it is too soon to tell for sure, some reports indicate that maintenance will be considerably less frequent because of the cleanliness of the fuel, causing the engine to remain more reliable and efficient.

**Is a special oil needed for the vehicle?** No. The same oil used in a gasoline-only car can be used in an NGV.

**Are NGVs safe in regards to accidents, leaks, etc.?** According to American Gas Association, NGVs are safe because the cylinders that contain the CNG are built to much more rigorous standards than gasoline tanks. A detailed 430 million mile study on NGVs reported only one minor injury and no fatalities associated with the fueling system. The cylinders and high pressure fuel line have undergone stringent tests, including dropping from heights, explosions, being shot at with high-powered weapons, and burning in fires. The cylinders have passed these test with few if any problems.

**Didn't some cylinders rupture?** Yes, cylinders on two General Motors pickup trucks ruptured in early 1994, one in San Francisco and one in Minneapolis. The ruptures, however, were caused by model-specific installation design flaws that resulted in a weakening

of the fiberglass wrap around the cylinders. GM recalled all the pickup trucks that were made with that cylinder design and reimbursed all buyers. After rigorous reviews of their own cylinder installation designs, other OEMs declared their vehicles safe and continued productions immediately.

**How do NGVs' exhaust emissions compare to that of a gasoline vehicle?** When compared to gasoline, a dedicated natural gas vehicle, on average, emits 60 to 80 percent less carbon monoxide, up to 50 percent less nitrogen oxides, and ozone reactivity is decreased by up to 90 percent when compared to gasoline. California's first certified LEVs and ULEVs were both NGVs from Chrysler.

**Are there incentives for purchasing natural gas vehicles?** Yes. The California Energy Commission offers incentives toward natural gas vehicles. Additionally, the State of California offers a \$1,000 tax credit on vehicles that are certified as low emission by the California Air Resources Board and \$1,500 on vehicles certified as ULEV. The tax credit for California is based on the differential cost of equipping the vehicle to use the clean fuel — the amount above the price of a regular gasoline-only model.

The federal government also offers a tax credit up to a maximum of \$2,000 for clean-fuel vehicles that use alternative fuels such as ethanol, methanol, propane or natural gas.

Rebates may also be available from the automaker. Ford, for example, is offering \$2,500 in rebates on its NGV Crown Victoria.

## Questions About Natural Gas

**What is Compressed Natural Gas?** CNG is a highly compressed form of the same fuel used in our households for cooking and heating. It is a combustible, gaseous mixture of simple hydrocarbon compounds, usually found in deep underground reservoirs formed by porous rock. Natural gas is a fossil fuel and can be found by itself or in association with crude oil or hydrocarbon condensates — gases that liquefy at normal atmospheric pressures and closely resemble mineral spirits. Natural gas is primarily composed of methane (CH<sub>4</sub>), with minor amounts of ethane (C<sub>2</sub>H<sub>6</sub>), propane (C<sub>3</sub>H<sub>8</sub>), butane (C<sub>4</sub>H<sub>10</sub>) and pentane (C<sub>5</sub>H<sub>12</sub>).

Natural gas has an ignition temperature of about 1,200 degrees Fahrenheit, about 600 degrees higher than gasoline. The heating value of natural gas depends on the proportion of gases making up the mixture. Most commercial natural gas has a heating value from 960 to 1,120 British thermal units (Btu) per cubic foot, with a rough average of 1,025 Btu/cubic foot or 102,500 Btu per therm.

Natural gas has been used for many years in stationary internal combustion engines with extremely high efficiency and reliability, but it hasn't been until recently that auto companies have begun offering factory-produced NGVs.

**How is natural gas produced?** Natural gas is exactly what it says — natural. Natural gas is a fossil fuel that is found in reservoirs 3,000 to 15,000 feet below the surface. In California, the typical natural gas-producing reservoir is found at depths of 6,000 to 8,000 feet. Because of its low density, natural gas does not have to be pumped from the reservoir to the surface wellhead.

Natural gas is not a petroleum product and is abundantly available in North America. Because it is a fossil fuel, however, there is a finite supply on the planet — estimated at 120 years at current levels of consumption and with known reserves. Its use as a transportation fuel will lessen our dependence on petroleum products. California's extensive network of natural gas pipelines can deliver the fuel directly to many sites through environmentally safe infrastructure, where compressors can be simply installed where needed.

**How does CNG's octane rating compare to gasoline and M85 ?** Natural gas has an octane rating of 130 as compared to super unleaded gasoline with an octane rating of only 92 and regular unleaded with an octane rating of 87. M85, by comparison, has an octane rating of 102.

**Is there an increase in performance with CNG?** With a retrofitted or converted vehicle, there may be a 5-10 percent power loss, but with a dedicated NGV, the loss can be overcome and there may be up to a 10 percent increase in power because the vehicle's compression ratio is changed to take advantage of the higher octane rating.

**Is CNG more toxic or dangerous than gasoline?** Natural gas is identified as non-toxic in that exposure to it won't cause injury. Breathing of natural gas, however, could be dangerous as it could cause asphyxiation.

**Is there a fire hazard associated with CNG?** Natural gas is lighter than air. Because of this, if natural gas were to be released or accidentally leaked, it would rapidly disperse. In addition to this, before the gas can actually ignite, it would have to mix with 6 to 16 percent air, which is unlikely unless designed to do so under specific conditions.

**What is the difference between CNG and propane (liquefied petroleum gas or LPG)?** Propane is a fossil fuel bi-product of natural gas processing and petroleum refining that is in a gaseous form at normal pressures and liquefies at relatively low pressure. LPG typically is made up of propane and butanes. It also has a lower octane, a lower energy content (though LPG has a high energy content per volume) and is more volatile than natural gas. LPG is also heavier than air and will sink to the ground and “pool.” Natural gas is lighter than air and dissipates readily.

**What is the difference between CNG and LNG (liquefied natural gas)?** LNG is natural gas that has been liquefied for easy storage or transport. Natural gas is turned into a liquid by extreme cooling to **minus** 327.2 degrees Fahrenheit. LNG is almost pure methane, and because it is a liquid, has an energy storage density much closer to gasoline than CNG. The requirements of keeping the liquid very cold, however, and its volatility make its applications more limited for transportation purposes. Some demonstrations are currently being undertaken to look at LNG for heavy-duty applications such as transit buses, heavy-duty long-haul trucks or locomotives.

**What is the price of CNG?** Fuel for NGVs costs about \$0.70 to \$1.00 when compared to its equivalent of one gallon of gasoline. This price varies according to local natural gas utility service area. The prices charged by natural gas utility companies for natural gas are approved by the California Public Utilities Commission. Non-utilities sell CNG at market prices. CNG and electricity, however, are not yet fully taxed at gasoline-equivalent rates. Combined state and federal taxes on LPG are more than the gasoline equivalent. In California, methanol and ethanol are taxed based on energy content compared to gasoline.

## Questions and Answers About California’s Natural Gas Supplies

**Where does California get its natural gas?** California gets its natural gas from both in and out of the state sources. Out of state sources, however, still remain in North America. According to the Energy Commission’s *1991 Fuels Report*, in 1991, 57 percent of California’s natural gas came from the U.S. Southwest, 21 percent from Canada, 19 percent from within state, and 3 percent from the Rocky Mountain area. In the year 2011, this is projected to change to 43 percent Southwest, 29 percent Canada, 18 percent from Rocky Mountain area, and 10 percent within state.

The American Gas Association estimated that if 1.7 million vehicles in the United States ran on natural gas, the supply needed would equal just 0.9 percent of the amount of natural gas produced in North America in 1988. The Energy Commission forecasts that in 2013, NGVs in California will use just under seven percent of the state’s total amount of natural gas consumed (484 million cubic feet per day).

**How does natural gas get to the consumer?** California is criss-crossed with tens-of-thousands of miles of natural gas pipelines. Natural gas comes into the state from large diameter pipelines that normally operate at 250- to 1,000 pounds per square inch gauge (psig) pressure. Transmission lines transfer natural gas from a gathering line (production intertie) or storage facility to a distribution center or another storage facility. From there, natural gas is distributed to customers through either a 60-psig high-pressure distribution system or a low-pressure system that delivers natural gas to a residential gas meter at 1/4 psig. For refueling NGVs, the gas must be pressurized to 3,000 to 3,600 psig to fill the vehicle’s cylinders. Typical CNG delivery pressure in California is 3,200 psig.

**Who sells compressed natural gas?** CNG is sold by natural gas utility companies and through a limited number of major gasoline retailers. Independent CNG retailers have also entered the market. In California, the utilities are City of Long Beach Gas Department, Pacific Gas and Electric Company, San Diego Gas and Electric Company, and Southern California Gas Company. Shell, Unocal, Chevron and Texaco also sell CNG, as do FleetStar and MESA at a growing number of outlets.

**Where can CNG be purchased?** By December 1995, 175 NGV fueling stations were in existence throughout California (see map in Chapter 10). Of these stations, 106 have full or limited access to the public and 69 are private. Some of the public facilities are at regular gasoline service stations through contracts the natural gas utility companies have with Chevron, Shell, Texaco and Unocal.

**What is the cost of installing CNG refueling equipment? Can the equipment be installed for a public or private fleet? What about refueling at home?** For a small private or public fleet of about ten vehicles, installation of fast-fill compressor facilities can cost between \$180,000 to \$250,000. A public access facility can cost up to \$500,000. Quick-fill facilities for larger numbers of vehicles, such as a transit company, can be more expensive — as much as \$3.5 million for the Sacramento Regional Transit District's natural gas bus refueling facility. Small, slow-fill refueling units can also be installed in a home for about \$3,500, which will refuel a single vehicle overnight. Prices on these type of compressors are expected to drop and may, in the future, even be rented to residential customers who use NGVs.

**How are the current fueling systems accessed?** All public access facilities are accessed through a fuel card known as the Tech 21. This card is available through the local natural gas utility company.

## NGV Model History

Chrysler's Dodge full-size *B-350 RAM Van*, powered by CNG, was the first vehicle to be certified as a Low Emission Vehicle by the California Air Resources Board. The van is being offered for sale in California and other states and is especially popular as a van pool vehicle. In February 1993, Chrysler officials, along with the Southern California Gas Company and the Gas Research Institute, announced that Chrysler would sell a dedicated CNG minivan by 1994. In January 1994, the California Air Resources Board announced that the Chrysler/Dodge Natural Gas-powered *Minivan* was the first vehicle to be certified as an Ultra-Low Emission Vehicle. The auto company also announced that both the full-size van and the minivan were available for sale to fleets and the public in 1995 and beyond. Chrysler officials say they can build up to 2,000 or more of each model per year. In the 1996 model year Chrysler will offer a Dodge *Dakota* Pickup and the Dodge *RAM Pickup* as LEV NGVs, as well as the

ULEV *Caravan* minivan.

In 1992 and 1993, Ford produced a limited number of Crown Victoria sedans and other vehicles powered by natural gas. These demonstration vehicles were distributed to natural gas utility companies for testing and evaluation purposes. In early 1994, Ford announced its intentions to produce natural gas F-series pickup trucks, full-size vans and *Crown Victoria* sedans for sale to fleets and the general public. In 1996, Ford began offering the first factory-built dedicated NGV, the *Crown Victoria* sedan, for sale to the public. The company also offers its F-Series pickup trucks and Econoline vans with configurations to run on gasoline and either natural gas or propane.

General Motors produced 2,500 GMC *Sierra* and Chevrolet 1992 and 1993 model year 3/4-ton pickup trucks to run on natural gas. In the 1994 model year, GM had planned to offer a full line up of bi-fuel natural gas vehicles. These vehicles could switch from natural gas to gasoline when on-board supplies of natural gas were too low. Bi-fuel models that were to be offered included a Chevrolet *Corsica* and *Caprice*, 1/2- and 3/4-ton pickup trucks, a full-sized van, and various configurations of other specialty vehicles. In early 1994, however, two cylinders mounted on GMC pickup trucks ruptured because of poor cylinder design. One instance occurred in San Francisco and the other in Minneapolis. This prompted GM to recall its 2,500 1992–1993 GMC *Sierra* and Chevrolet NGV pickup trucks. The company also announced it was suspending all sales of its bi-fuel vehicles for the 1994–95 model year.

Foreign automobile companies are also interested in the use of natural gas in their vehicles. In January 1994, Honda unveiled an *Accord* model dedicated natural gas vehicle at the Greater Los Angeles Auto Show. The company said it plans to offer the vehicle sometime in the future, but would make no statements about its marketing strategy. Honda is currently testing CNG-powered *Civics* in utility company fleets. Other manufacturers are noncommittal about plans for NGV sales in California.

## NGVs Being Used/Sold

In 1996, all major auto manufacturers offer compressed natural gas models. Ford offers the factory-built *Crown Vic Ltd.* and other vehicles through its "QVMs" — Qualified Vehicle Modifiers. These are companies that perform vehicle conversions under the manufacturers' auspices, with the converted vehicle sold, serviced and warranted by Ford.

Other certified vehicles being offered for sale are listed on the next page.

## Recent Natural Gas Light-Duty Vehicles

Manufacturer	Model	Status
<b>Passenger Cars</b>		
Ford	Crown Victoria .....	Available (ULEV certified)
GM	Chevrolet Caprice .....	Prototype
	Chevrolet Corsica .....	Prototype
Honda	Civic .....	Demo
<b>Vans</b>		
Chrysler	Dodge B2500 RAM Van/Wagon .	Available (ULEV certified)
	Dodge B3500 RAM Van/Wagon .	Available (ULEV certified)
	Dodge Caravan .....	Available (ULEV certified)
	Plymouth Voyager .....	Available (ULEV certified)
Ford	Econoline 250 .....	Bi-fuel (gasoline/CNG)
	Econoline 350 .....	Bi-fuel (gasoline/CNG)
<b>Pickups</b>		
Chrysler	Dodge 2500 RAM Pickup .....	Available (ULEV certified)
	Dodge Dakota Pickup .....	Available (ULEV certified)
	Dodge RAM 1500 Pickup .....	Available (ULEV certified)
Ford	Ford F-150 Pickup .....	Bi-Fuel (gasoline/CNG)
	Ford F-250 Pickup .....	Bi-Fuel (gasoline/CNG)
GM	GMC Sierra Pickup .....	Prototype
	Chevrolet Pickup .....	Prototype

## Current Air Resources Board – Certified Light-Duty NGVs

(As of February 1, 1996)

1996 Dodge Caravan/Plymouth Voyager Minivan (ULEV)

1995 Dodge 1500 RAM Pickup (ULEV)

1996 Dodge 2500 RAM Pickup (ULEV)

1996 Dodge B2500 RAM Van /Wagon (ULEV)

1996 Dodge B3500 RAM Van/Wagon (ULEV)

1996 Dodge Dakota Pickup (ULEV)

1996 Ford Crown Victroia LTD (ULEV)

1996 Ford Econoline 250, 350 Bi-fuel Van (bi-fuel, Tier-1)

1996 Ford F-150, F-250 Bi-fuel Pickup (bi-fuel, Tier-1)

## NGV Contacts

### Auto Makers

A. Michel Clement  
Alternative Fuels Vehicle Marketing  
Chrysler Corporation  
12000 Chrysler Drive  
CIMS 414-03-44  
Highland Park, MI 48288  
313-956-4599

Lou Ulrich  
Account Executive  
Fleet Sales Dept.  
General Fleet Office  
Ford Division  
2099 South State College Blvd.  
Suite 600  
Anaheim, CA 92816  
714-939-3562

Randy Berlin  
Account Executive  
Fleet Sales Dept.  
General Fleet Office  
Ford Division  
P.O. Box 9048  
Pleasanton, CA 94566  
510-463-5758

Ford Motor Company  
Alternative Fuel Vehicle Hotline  
1-800-ALT-FUEL (258-3835)

Gerald J. Barnes  
Manager  
Automotive Emissions Contrail  
General Motors Corporation  
3044 West Grand Blvd.  
Detroit, MI 48202  
313-556-7723

Robert J. Bienenfeld  
Manager, Market Development  
American Honda Motor Co. INC.  
1919 Torrance Bl.  
Torrance, CA 90501-2746

### California Fuel Providers

City of Coalinga Gas Service  
160 West Elm Street  
Coalinga, CA 93210  
209-935-1531

Dale Holdman  
City of Long Beach Gas Department  
2400 East Spring Street  
Long Beach, CA 90806  
310-570-2052

Clean Air Fuels Corporation  
Dr. Dragos Sfinteanu

1945 Las Plumas Ave.  
San Jose, CA 95133  
408-259-5710  
(CNG fueling station provider)

Michael Boucher  
Manager, Western Region  
FleetStar Inc.  
25251 Paseo de Alicia, Suite 200  
Laguna Hills, CA 92653  
714-72-9599

Brian Pepper  
Clean Air Vehicles  
Market Development  
Pacific Gas and Electric Company  
123 Mission Street, Room H-2537  
P.O. Box 770000  
San Francisco, CA 94177  
415-973-2471

Bill Sessa  
News Services Bureau Chief  
Pacific Gas and Electric Company  
925 L Street, Suite 890  
Sacramento, CA 95814  
916-446-6616

Andrew Littlefair  
Vice President, Public Affairs  
MESA  
2600m Trammell Crow Center  
2001 Ross Avenue  
Dallas, TX 75201  
214-969-2208

Joe Semerad  
Natural Gas Vehicle Marketing  
San Diego Gas & Electric  
8306 Century Park Court, Suite 4200  
San Diego, CA 92123  
619-654-1108

Stephanie Donovan  
Media & Public Relations  
Alternative Fuel Vehicles  
San Diego Gas & Electric  
8306 Century Park Court  
San Diego, CA 92123  
619-696-4285

Michael R. Marelli  
Natural Gas Vehicle Service Manager  
Southern California Gas Company  
P.O. Box 3249, ML 25DO  
Los Angeles, CA 90051-1249  
800-GAS-2000

Denise King  
News Bureau  
Southern California Gas Company  
555 West 5th Street  
Los Angeles, CA 90017  
213-244-2548

Ken Olsen  
Manager of Research  
Southern California Gas Company

ML 19EO  
P.O. Box 3249  
Los Angeles, CA 90051  
213-244-5350

Southwest Gas Corporation  
P.O. Box 15015  
Las Vegas, NV 89114  
702-876-7011

Universal Organic Resources Inc.  
Fred Golisanc, President  
P.O. Box 3149  
Half Moon, Bay, CA 94019  
415-726-2740  
(natural gas and CNG supplier)

### Conversion Kit Companies

(Note: Check with California Air Resources Board for **latest list of approved** conversion kits.)

Algas Carburetion  
16101 Vallen Drive  
Houston, TX 77041

Automotive Natural Gas Inc.  
265 North Janesville St.  
Milton, WI 53563  
608-868-4626

Beam Products Manufacturing Company  
3040 Rosslyn Street  
Los Angeles, CA 90065

Beacon Power Systems  
447 E. Elmwood  
Troy, MI 48083

Carburetion Labs  
515 N.E. 190 Street  
Miami, FL 33179

Century Products  
(Formerly Vialle Autogas Systemen)  
9101 Ely Road  
Pensacola, FL 32514

Challenger Energy Products  
702 W. 48th Ave.  
Denver, CO 80216

Clean Fuels  
3125 W. Bolt  
Ft. Worth, TX 76110

College of the Desert  
Energy technology Training Center  
Attn: Colin Messer  
43500 Monterey Ave.  
Palm Desert, CA 92260  
619-773-2545  
(student training classes in NGVs)

Dual Fuel Systems Inc.  
Subsidiary of Pacific Lighting Corp.  
1120 Maple  
Montebello, CA 90640

Essex Cryogenics  
8007 Chivvis Drive  
St. Louis, MO 63123

Impco Carburetion Inc.  
16916 Gridley Pl.  
Cerritos, CA 90701  
213-860-6666

Mesa Environmental  
3125 West Bolt Street  
Fort Worth, TX 76110

Metropane Inc.  
2772 Sawbury Rd.  
Columbus, OH 43235

Mogas Sales  
4467 Juneao St.  
Burnaby, B.C.  
CANADA V5C 4C4

Natural Fuels Corp.  
5865 Stapleton Dr., N.  
Denver, CO 80216

NGV Development  
2250 Cherry Industrial Circle  
Long Beach, CA 90805

PAS Inc.  
570 Executive Dr.  
Troy, MI 48083

Stewart & Stevenson  
5840 Dahlia St.  
Commerce City, CO 80022

Tren Fuels  
701 Brazos #520  
Austin, TX 78701

Vialle U.S.A. Inc.  
(Formerly Vialle Autogas Systemen)  
9101 Ely Rd.  
Pensacola, FL 32514

## Home Compressor Equipment

Fuelmaker Inc.  
P.O. Box 11865  
Salt Lake City, UT 84147  
801-530-2859

RIX Industries  
6460 Hollis St.  
Oakland, CA 94608  
510-658-5275

## Government

California Energy Commission  
Transportation Technology & Fuels Office  
1516 Ninth Street, MS-41  
Sacramento, CA 95814  
916-654-4634

Ruth Anne Keister  
Manager  
Clean Cities Hotline  
P.O. Box 12316  
Arlington, VA 22209  
1-800-C-CITIES

George Karbowski  
Alternative Fuels Supervisor  
Metropolitan Transportation Authority  
900 Lyon Street  
Los Angeles, CA 90012  
213-972-5866

Toros Topaloglu  
Ministry of Transportation of Ontario  
1201 Wilson Avenue  
Downstream, Ontario  
CANADA M3M 1J8  
416-235-5017

Linda Bluestein  
Contract Manager  
National Alternative Fuels Hotline  
P.O. Box 12316  
Arlington, VA 22209  
800-423-1DOE (1363)

National Appropriate Technology  
Assistance Service (NATAS)  
P.O. Box 2525  
Butte, MT 59702  
800-428-2525

Brent Bailey  
National Renewable Energy  
Laboratory  
1617 Cole Blvd.  
Golden, CO 80401  
303-231-1288

New York State Energy Research &  
Development Authority  
Two Rockefeller Plaza  
Albany, NY 12223  
508-465-6251 ext 226

Texas General Land Office  
1700 North Congress  
Austin, TX 78701  
800-638-3599

Richard Wares  
Program Manager  
Office of Alternative Fuels  
U.S. Department of Energy  
1000 Independence Avenue, S.W.  
Washington, DC 25085  
202-586-8031

John Mueller  
National Vehicle  
& Fuel Emissions Laboratory  
U.S. Environmental Protection Agency  
2565 Plymouth Road  
Ann Arbor, MI 48105  
313-668-4275

Tad Wysor  
Clean Fuel Fleets Program  
U.S. Environmental Protection Agency  
2656 Plymouth Road  
Ann Arbor, MI 48105  
313-668-4332  
David Gushee  
Senior Specialist, Environmental Policy  
U.S. Library of Congress  
Congressional Research Service  
Washington, DC 20540  
202-707-7228

## Organizations

E. Eugene Ecklund  
Executive Director  
Alternative Transportation Fuels  
Foundation  
HCR-72, Box 547-B LOW  
Locust Grove, VA 22508  
703-972-0484

Greg Zilberfarb  
Director, NGV Marketing  
American Gas Association  
1515 Wilson Blvd.  
Arlington, VA 22209  
703-841-8574

Robert Cumming  
Canadian Gas Association  
950 Burnhamthorpe Road W.  
Mississauga, Ontario  
CANADA L5C 3B4  
416-897-1690

Edward Farkas  
Senior Engineer  
Canadian Gas Research Institute  
55 Scarsdale Road  
Don Mills, Ontario  
CANADA M3R 2R3  
416-447-6465

Wayne Parker  
General Manager  
Clean Air Vehicle Association  
14 Piedmont Center, Suite 1205  
Atlanta, GA 30305  
404-237-1980

Ginny Hobbs-Moore  
CNG & LNG Research Programs  
Gas Research Institute  
8600 Bryn Mawr Avenue  
Chicago, IL 60631  
312-399-8100

Norm Yale  
Project Manager  
Gas Research Institute  
8600 W. Bryn Mawr Avenue  
Chicago, IL 60631  
312-399-5414

William Vavrik  
Institute of Gas Technology  
3424 S. State Street  
Chicago, IL 60616  
312-567-3877

David P. Lefever  
Executive Director  
National Assn. of Fleet Administrators  
100 Wood Avenue South, Suite 310  
Islelin, NJ 08830  
908-494-8100

Ted Lemoss  
(NGV & Fire Code Research)  
National Fire Prevention Association  
One Batterymarch Park  
P.O. Box 9101  
Quincy, MA 02269  
617-984-7407

Natural Gas Vehicle Coalition  
1515 Wilson Blvd.  
Arlington, VA 22209  
703-527-3022

Gregory Vlasek  
Executive Director  
Natural Gas Vehicle Coalition  
925 L Street, Suite 1485  
Sacramento, CA 95814  
916-448-5036

David DuBois  
Society of Automotive Engineers (SAE)  
400 Commonwealth Drive  
Warrendale, PA 15095

# Chapter 7

## Propane / LPG-Powered Vehicles



### Overview

More than 350,000 vehicles, mostly in fleets, are traveling the nation's highways under propane power. Also known as LPG (or liquefied petroleum gas, a category that also includes butane and ethane), propane is powering taxis in Las Vegas; school buses in Kansas City and Portland, Oregon; sheriff and police cars in other communities; and in dozens of fleets around California. Propane is used in both light- and medium-duty vehicles. Estimates have placed the number of registered vehicles in California that are powered by propane as high as 40,000. Propane has been used as a transportation fuel for more than 60 years around the world.

Propane is a gas in its natural state. It turns to liquid under moderate pressure and is stored in vehicle fuel tanks at about 200 pounds per square inch. When liquid propane is drawn from the tank, it changes back to a gas before it is burned in the engine. Propane is a by-product of petroleum refining and from natural gas production. In California, propane is mostly produced from the petroleum refining process, though across the country, propane is mostly a by-product of natural gas production. The federal government lists propane as an alternative fuel.

Propane is a clean fuel which offers a range closest to gasoline. One gallon of propane contains less energy than a gallon of gasoline (82,485 Btu for propane versus 115,400 Btu for gasoline), but propane companies say the miles per gallon should be about equal if the vehicle is tuned properly. LPG engine efficiency and fuel economy remain a subject of study and debate. Industry claims of equal miles per gallon with gasoline do not appear readily verifiable.

Compared to gasoline, propane vehicles emit about one-third less reactive organic gases, reduce nitrogen oxides by about 20 percent, and show a reduction of about 60 percent in carbon monoxide.

Propane is widely available in urban areas or refueling facilities can be installed on-site for fleet use. It can also be found in rural areas, where propane is used for heating and cooking and where natural gas is not available, and at service stations that refuel recreational vehicles' propane tanks.

Converting an automobile or light-duty truck from gasoline to propane costs about \$1,000 - \$2,000 and can usually be done in one day. Conversions must comply with safety standards set by the National Fire Protection Association, and kits must be certified by the California Air Resources Board. (Contact ARB for its latest list of certified equipment and installers.) Modifications typically include: a heavy steel or high-strength fuel tank added to the trunk or truck bed, fuel lock filter/shut-off valve, vaporizer/regulator, and air/fuel mixer. Conversion kit parts are reusable. Dual-fuel gasoline/propane systems are also currently available.

A drawback commonly cited about propane vehicles is the loss of trunk space in dual-fuel passenger vehicles due to installation of the tank, which is about the size of a spare tire or larger.

On the positive side, propane-powered vehicles have less carbon build-up compared to gasoline- and diesel-powered vehicles. According to the National Propane Gas Association, spark plugs from a propane vehicle last from 80,000 to 100,000 miles and propane engines can last two to three times longer than gasoline or diesel engines.

Propane retail prices were, on average, about the same as unleaded gasoline prices during the late 1980s and 1990s. The Energy Commission forecasts future propane prices as less expensive than gasoline. Propane prices, however, can fluctuate widely and are often tied to oil prices. Shortages of propane, such as the shortage in New England during a cold wave a number of years ago, can also increase propane prices quickly.

The Energy Commission is involved in a side-by-side comparison of 113 fleet delivery vehicles in Southern California. Propane is one of the five fuels being studied in the \$11 million CleanFleet program. Federal Express is the fleet operator, and Battelle Memorial Institute is the technical contractor. The two-year test program concluded in October 1994.

## Current Vehicles Offered For Sale

Some auto manufacturers are offering a propane option (in passenger cars, vans and pickup trucks) in their model line-up or offering engines that have been optimized for gaseous fuels. It would then be up to the purchaser to have the vehicle converted to propane with third-party equipment. Ford is selling its *F-700* series medium-duty truck with a California Air Resources Board-certified propane engine option. The vehicle requires only permanent installation of the LPG tank. Chevrolet offers its 5.7 liter V-8 pickup truck/van engine with a "propane prep engine" option.

For more information about propane in California, contact:

Western Propane Gas Association ..... (916) 962-2280

Propane Vehciel Council ..... (714) 253-5757

For the latest list of Approved Alternative Fuel Conversion Systems, contact the California Air Resources Board Certification Branch at (818) 575-6800, or call ARB Public Information toll-free at (800) 242-4450.

## LPG / Propane Contact List

### Conversion Equipment Companies

(Note: Check with Air Resources Board for latest list of Approved Conversion Systems.)

Advanced LP Systems Inc.  
5327- Jacuzzi St.  
Richmond, CA 94804

Algas Corporation  
16101 Vallen Drive  
Houston, TX 77041

Bean Products Manufacturing  
Company  
3040 Rosslyn St.  
Los Angeles, CA 90065

Carburetion Labs  
515 N.E. 190 Street  
Miami, FL 33179

Eagle Propane  
1871 Lake Place  
Ontario, CA 91761

Greenway Environmental Research  
40208 Industrial Park Circle  
Georgetown, TX 78626

Halley Replacement Parts Division  
Colt Industries Operating Corp.  
11955 East Nine Mile Rd.  
Warren, MI 48090

Impco Carburetion Inc.  
16916 Gridley Pl.  
Cerritos, CA 90701  
213-860-6666

Landi-Hartzog, U.S. Inc.  
3208 South Hutchison Ave.  
Los Angeles, CA 90034

LFF Carburetion Inc.  
P.O. Box 522  
Hutchison, KA 67501

Marvel Schleber/Tillotson  
Division of Borg Warner Corp.  
2195 South Elwin Rd.  
Decatur, IL 62625

OHG Inc.  
10065A Greenleaf Ave.  
Santa Fe Springs, CA 90670

Toyo Red Cab LPG Conversion  
16609 South Halldale Ave.  
Gardena, CA 90247

Vialle U.S.A. Inc.  
(Formerly Vialle Autogas Systemen)  
9101 Ely Rd.  
Pensacola, FL 32514

### Government

California Energy Commission  
Transportation Technology and Fuels Office  
1516 Ninth Street, MS-41  
Sacramento, CA 95814  
916-654-4634

John Mueller  
National Vehicle  
& Fuel Emissions Laboratory  
U.S. Environmental Protection Agency  
2565 Plymouth Road  
Ann Arbor, MI 48105  
313-668-4275

### Organizations

Bob Myers  
Technical Consultant  
Propane Vehicle Council  
2102 Business Center Dr., Suite 130  
Irvine, CA 92714  
714-253-5757

Rita Pecilunas  
Director of Marketing  
National Propane Gas Association  
1600 Eisenhower Lane  
Lisle, IL 60532  
708-515-0600

Lisa Bontempo  
Government Relations  
National Propane Gas Association  
4301 Fairfax Drive, Suite 340  
Arlington, VA 22203  
703-351-7500

Rick Roldan  
Executive Director  
Propane Vehicle Council  
901 15th St., N.W., Suite 700  
Washington, DC 20005  
202-371-6262

Mary Mulrooney-Reynolds  
Executive Vice-President  
Western Propane Gas Association  
7844 Madison Ave., Suite 150  
Fair Oaks, CA 95628  
916-962-2280

# Chapter 8

## Alternative Fuel Heavy-Duty Vehicles & Engines

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Since October 1989, the California Energy Commission has tested the use of alternative fuels in heavy-duty engines and vehicles. Initially, methanol was tested, and in mid-1992, compressed natural gas heavy-duty engines were added to the program. The Energy Commission has also worked with various bus manufacturing companies to put alternatively fueled transit and school buses on the road.

The demonstration program tests the feasibility of using cleaner-burning fuels in heavy-duty trucks and buses to diversify California's transportation fuels and to help improve California's air quality. The Commission has studied alternative transportation fuels since 1978. A number of fuels have been successful in establishing competition with conventional fuels and engine designs to achieve long-range energy diversity and air quality goals for California.

### Heavy-Duty Truck Program

The Commission initially brought together engine manufacturers with host demonstration sites in unique public/private partnerships with methanol. The South Coast Air Quality Management District (SCAQMD) and Air Products Inc. later joined with cost-shared support.

Southern California Gas Company, the Department of Energy's National Renewable Energy Laboratory and the American Trucking Association Foundation, the Trucking Research Institute, and the Ventura County Air Pollution Control District joined the program in sponsorship of compressed natural gas and later liquified natural gas. The Energy Commission has provided a total of \$1,668,243 to cost-share these demonstrations of heavy-duty vehicles with the co-funding agency; bringing the total funding to \$6,339,370. The engine manufacturers provide new engines designed to run on alternative fuels. The host sites provide vehicles for the new alternative fuel engines, as well as operation, maintenance and fuel. The sponsors cost-share engine technology, provide technical support, and compile and analyze data on the test vehicles.

Participating in the program were five engine

manufacturers (Detroit Diesel Corporation [DDC], Caterpillar, Cummins, Ford and Navistar) and 12 host sites (Arrowhead Drinking Water Company; Cities of Glendale, Los Angeles, and South Lake Tahoe; the County of Sacramento and the Los Angeles County Sanitation Districts; Federal Express and Golden State Foods with Penske Truck Leasing; Waste Management Inc.; the Vons Companies Incorporated; the Los Angeles Times/Times Mirror Corporation; and the Port of Long Beach).

The Energy Commission is also supporting the demonstration of natural gas vehicles in the U.S. Department of Energy's "Heavy-Duty State/Municipal Alternative Fuel Vehicle Demonstration Program" via subgrants to the Cities of Long Beach and Berkeley.

### Why the Focus on Methanol and Natural Gas?

Methanol and compressed natural gas provide two benefits over diesel: energy diversity and air quality. Methanol is a clean-burning liquid fuel that can be made from natural gas, coal or biomass. Natural gas is a clean-burning and widely available gaseous fuel that can be compressed or liquefied for use by heavy-duty vehicles.

Using these domestic resources can decrease dependence on petroleum. The two fuels are the closest major competitors (in terms of technology and availability) to diesel, though new developments in ethanol and other biofuels show promise.

Methanol trucks in the Heavy-Duty Demonstration Program use M100 (100 percent methanol) or M85 (85 percent methanol and 15 percent unleaded gasoline) dispensed from private fuel stations and a network of more than 50 public stations.

Natural gas trucks in the Demonstration Program use pipeline natural gas compressed at a network of more than 175 public and private fueling facilities sponsored by gas utilities. The L.A. County Sanitation Districts are using "cleaned" landfill gas (called CLG and made up of mostly methane) in their truck. Other natural gas trucks with similar engines will use LNG (liquefied natural gas), a cryogenic liquid that may

allow trucks to achieve ranges found on conventional diesel trucks.

Heavy-duty trucks and buses are now required to meet strict 1996 state and federal clean air standards. Current methanol and natural gas heavy-duty engine technology can meet the much tougher emission standards established or planned for 1998 and beyond. Methanol and natural gas trucks reduce both visible smoke and invisible particulates and nitrogen oxide emissions and particulate emissions, all of which represent public health hazards and contribute to poor air quality.

In August 1991, the U.S. Environmental Protection Agency and the California Air Resources Board certified Detroit Diesel's 6V-92 methanol engine as the first heavy-duty production engine to meet the tougher standards. The Los Angeles County Metropolitan Transportation Authority (MTA, formerly Southern California Rapid Transit District) has been exploring the use of ethanol (with minor electronic calibration) in some of its 339 methanol transit buses currently serving Los Angeles with DDC methanol engines. Methanol prices spiked in late 1994 to early 1995, due to increased demand on oxygenates made from methanol, but it has since returned to stable levels. MTA also wanted to determine if ethanol would provide improved operations.

In 1993, the Cummins L10-240G was certified by EPA and ARB to achieve similar low emission levels on compressed natural gas. The Sacramento Regional Transit District has nearly 100 transit buses currently serving Sacramento with Cummins natural gas engines. Other transit districts are using natural gas buses.

## Safe School Bus Clean Fuel Efficiency Demonstration Program

Legislation signed into law in 1988 by Governor George Deukmejian and authored by Assemblyman Richard Katz (AB 35) appropriated \$60 million for the Safe School Bus Clean Fuel Efficiency Demonstration Program. Funding comes from the Petroleum Violation Escrow Account (PVEA). These funds, collected and dispersed by the federal government, are fines paid by oil companies that overcharged consumers in the 1970s. The \$60 million was augmented by another \$40 million in additional PVEA appropriations, bringing the total program to \$100 million.

The initial \$60 million was used to purchase buses in two phases — \$20 million to purchase 163 buses in Phase 1 and \$40 million to purchase 400 buses in

Phase-2. An additional 218 buses were purchased in Phase 3 with the additional PVEA augmentation. Buses for the third phase will be delivered starting in June 1996.

The overall objectives of this program are: to demonstrate direct energy savings without causing adverse air quality impacts, reduce tax dollars wasted in vehicles that are not fuel efficient, and promote use of state-of-the-art safety features in school buses.

This project allows school districts to upgrade their fleets in a cost-effective manner and replace buses that were built prior to the 1977 Federal Motor Vehicle Safety Standards. The older buses being replaced will not be allowed to transport school children or workers within California. Most of them will either be "parted out" or scrapped.

To help achieve the objectives of the program, at least 35 percent of the replacement school buses have to be powered by low-emission, clean-burning fuels such as methanol (methyl alcohol) or compressed natural gas.

## Criteria for Evaluation

Local educational agencies of all sizes, geographic areas and climate zones were considered as potential sites and candidates for the first two phases of this demonstration program. Energy Commission staff evaluated scores of proposals that were submitted for funding under both phases. Criteria for the final selection of districts and consortiums included:

- Local school district fleet composition based on percent of vehicles built prior to the 1977 Federal Motor Vehicle Safety Standards, the age of the buses targeted, total number of miles on targeted buses, miles driven during the school year, and fuel consumption of buses being replaced.
- Local school district capabilities to meet program requirements such as maintenance and fueling capabilities, resource contributions, cooperation and enthusiasm of local districts to the program, and contingency plans.
- Environmental considerations such as local air quality levels, including whether the district was in an air pollution non-attainment area, petroleum savings and geographic location.

## Alternative Fuel Heavy-Duty Truck Demonstration Program (As of March 1996)

<i>ORGANIZATION</i>	<i>TYPE</i>	<i>ENGINE</i>	<i>HP</i>	<i>CHASSIS</i>	<i>FUEL</i>
City of Los Angeles	Dump truck	Cummins L10	270	Peterbilt 379	M95 +A*
City of Los Angeles	Sludge hauler	DDC 6V-92TA	350	GMC-General	M100
City of Glendale	Refuse hauler	Cat. 3306 DITA	245	Peterbilt 320	M100
Golden State Foods	Tractor/trailer	DDC 6V-92TA	300	Freightliner	M100
Federal Express	Tractor/trailer	DDC 6L-71TA	300	Freightliner	M100
Arrowhead Water	Delivery truck	Ford 6.6L MX	170	Ford F800	M85
City of South Lake Tahoe	Dump truck/sander	Navistar DT-466	210	International 4800	M100/85
County of Sacramento	Flatbed truck	Navistar DT-466	210	International 4900	M100/85
Waste Management Co.	Refuse haulers (2)	DDC 6L-71TA	240	Volvo/White	M100
Port of Long Beach	Cargo Hostlers (2)	DDC 4L-71TA	200	Ottawa	M98 + A**
The Vons Companies Inc.	Tractor/trailer	Cat. G3406 Mobile	350	Ford LTLA-9000	CNG
The Los Angeles Times	Tractor/trailer	DDC Series 60G	370	Ford LTLA-9000	CNG
LA County Sanitation Dist.	Tractor/trailer	DDC Series 60G	370	Freightliner	CLG
City of Long Beach	Refuse Packer	Cummins L10	260	Crane Carrier	CNG
City of Berkeley	various vehicles	various engines	---	various	CNG

\* 95% Methanol plus 5% Avocet ignition improver. \*\* 98% Methanol plus 2% Avocet ignition improver.

### A Signal to School Bus Manufacturers

The Energy Commission's program has sent a signal to school bus manufacturers that California school districts will require advanced safety features, and high-efficiency and alternatively-fueled buses, both now and in the future. California's leadership role has influenced the school buses being built and used around the country.

In the first phase of the program, the 163 buses were built by Crown Coach Bus Company and Blue Bird Body Company and distributed to 14 school districts and consortiums. Crown Coach, formerly of Chino, California, built 103 advanced, high-efficiency diesel and 50 methanol-powered buses that used Detroit Diesel engines. Ten Blue Bird buses used General Motors chassis and were built by Blue Bird

Body Company of Fort Valley, Georgia, and distributed by Golden State Bus Sales of West Sacramento, California. These ten buses are powered by GMC 427 cubic inch V-8 engines converted by Tecogen of Waltham, Massachusetts, and use compressed natural gas (CNG).

The Tecogen Tecodrive 7000T natural gas engine and Detroit Diesel's methanol engine had been certified by the U.S. Environmental Protection Agency and the California Air Resources Board as meeting the 1994 heavy-duty vehicle emission standards.

In Phase 2 of the program, a total of 400 school buses will be built and distributed to 47 school districts and consortiums. Of these, 200 are high-efficiency diesel, 100 methanol-powered and 100 fueled by natural gas. The 78-passenger advanced diesel buses are built by Thomas Bus Company and are powered by a Caterpillar CAT 3116TA engine, rated at 229 horsepower. The 78-passenger methanol-fueled buses

are built by Carpenter using a Detroit Diesel Corporation DDC 6V-92TA engine, rated at 253 horsepower. The natural gas buses also will hold 78-students and are built by Blue Bird Bus Corporation using a Tecogen Tecodrive 7000T engine, rated at 222 horsepower.

Delivery of the Phase 2 buses began at the end of 1992 and was completed in the fall of 1993.

Phase 3 will expand the program based on findings from Phases 1 and 2. This phase included 107 natural gas buses, 107 advanced diesel buses and four electric buses, all manufactured by Blue Bird Bus Company. The CNG buses use John Deere engines. The electric buses use Westinghouse motors. Delivery of the Phase 3 buses begins in June 1996.

### Electric School Buses

Under a separate program, the Energy Commission and CALSTART, a consortium of companies and government entities working to develop advanced transportation technologies, are developing electric-powered school buses. A demonstration program under the Commission's Transportation Energy Technologies Advancement Program (TETAP) retrofit two 67-passenger, diesel-powered school buses to run on electricity and built one prototype electric school bus "from the ground up." The buses will be in service in the Goleta Union School District and the Santa Maria/Bonita School District, both in Santa Barbara County. The retrofit and prototype buses are being built by Bus Manufacturing USA Inc. of Santa Barbara, APS Systems of Oxnard and Specialty Vehicle Manufacturing Corporation of Downey. The cost of this demonstration project is \$192,700 of Energy Commission funds and \$823,000 of matching funds.

### Other Buses

The Commission's programs to move the bus manufacturers to alternative fuels is apparently working. In late 1994, Blue Bird Body Company began selling the first Original Equipment Manufacturer school bus powered by natural gas. The bus company, based in Georgia, is also testing an electric-powered school bus in the Antelope Valley School District and other school districts around the country.

### Additional Information on School Buses

For more information, please contact:

California Energy Commission  
Transportation Technology & Fuels Office  
Safe School Bus Clean Fuel Efficiency  
Demonstration Program  
1516 Ninth Street, MS-41  
Sacramento, CA 95814  
(916) 654-4685

## Air Resources Board – Certified Heavy-Duty Engines

(As of March 1996)

<i>Year</i>	<i>Manufacturer</i>	<i>Engine Use</i>	<i>Model/Size</i>	<i>Fuel Type</i>
1991	Detroit Diesel	School Bus, H-D Truck	DDC 6V-92TA	M85/M100
1991	Tecogen	School Bus	Tecodrive 7000T/7.0 liter	CNG
1992	Detroit Diesel	School Bus H-D Truck	DDC 6V-92	M85/M100
1993	Cummins	Transit Bus	L10-240G/10.0 liter	CNG
1994	Cummins	Transit Bus	L10-240G/10.0 liter	LNG
1994	Detroit Diesel	Bus, H-D Truck	Series 50/8.5 liter	CNG
1994	Tecogen	School Bus	Tecodrive 7000T/7.0 liter	CNG
1994/95	Ford	M-D/H-D Truck	F700/7.0 liter	LPG
1994	Hercules	M-D Truck, Shuttle Bus	GTA35/3.5 liter	CNG
1994	Hercules	M-D/H-D Truck, Bus	GTA 56/5.6 liter	CNG
1995	Caterpillar	Bus, H-D Truck	G3306/10.5 liter	CNG
1995	Deere & Company	School Bus, MHD	Series 450 6081HFN/8.1 liter	CNG
1995	Cummins	Transit bus	L10-260G/10.0 liter	CNG

### Other Heavy-Duty Engines Not Certified by ARB

<i>Year</i>	<i>Manufacturer</i>	<i>Engine Use</i>	<i>Model/Size</i>	<i>Fuel Type</i>
1990	Caterpillar	Demo	3306 DITA	M100
1990	Detroit Diesel	Demo	DDC 6L-71TA	M100
1991	Ford	Demo	Ford 6.6L MX	M85
1991	Navistar	Demo	DT-466	M85/M100
1992	Detroit Diesel	Prototype	6V92DI-NG	CNG
1992	Detroit Diesel	Prototype	6V92PI-NG	CNG
1993	Caterpillar	Demo	G3406 Mobile	CNG
1993	Detroit Diesel	Demo	Series 60G	CNG
1994	Caterpillar	Demo	G3306	CNG/LNG/LPG
1994	Caterpillar	Demo	G3406	CNG
1994	Caterpillar	Demo, marine use/boats	G3412	CNG/LNG
1994	Cummins	Bus, HD Truck Available	L10-260G	CNG
1994	Cummins	Demo	6B/5.9 Liter	CNG (LNG?)
1994	Cummins	Prototype	C8.3G	CNG/LNG
1994	Cummins	Prototype	M11-280-330G	CNG
1994	Cummins/SwRI *	Demo	NTC-400	CNG
1994	Detroit Diesel/Navistar	School Bus, MD Truck - Avail.	Series 30G/7.3 Liter	CNG
1994	Detroit Diesel	Demo	Series 60G	CNG
1994	John Deere	Demo	6081 HFN	CNG
1994	Mack/SwRI *	Prototype	E7	CNG
1994	Mercedes-Benz	Bus (Available in Brazil)	M 366 G, 5.96 Liter	CNG
1994	Navistar	HD Truck - Available	T444NG	CNG
1994	Tecogen	MD Truck - Available	TecoDrive 4.3 liter	CNG
1994	Volvo	Bus (Avail. in Europe)	Bases, 9.9 Liter	CNG

Note: \* SwRI = Southwest Research Institute; M-D = medium-duty; H-D = heavy-duty; M85 = 85% methanol, 15% gasoline; M100 = 100% methanol; CNG = compressed natural gas; LNG = liquefied natural gas; LPG = liquefied petroleum gas (propane).

# Contacts for Heavy-Duty Alternative Fuel Engines and Vehicles

## Engine/Vehicle Manufacturers

Geoffrey Ballard  
Chairman  
Ballard Power Systems  
(Fuel Cells for Transit Buses)  
107 - 980 West 1st Street  
Vancouver, British Columbia  
CANADA V7P 3N4  
604-986-9367

John Riet  
Project Manager,  
Alternative Fuels Manager  
Bus Industries of America  
5395 Maingate Drive  
Mississauga, Ontario  
CANADA L4W 1G6  
416-625-9510

Donald Dowdall  
Manager, Engine Emissions  
Caterpillar Inc.  
100 NE Adams St.  
Peoria, IL 61629  
309-675-5362

Kenneth Suda  
Senior Project Engineer  
Caterpillar Inc.  
100 NE Adams St.  
Peoria, IL 61629  
309-578-3806

James Sibley  
Technical Manager  
Caterpillar Inc.  
P.O. Box 610  
Mossville, IL 61552  
309-578-8329

Clark Ahrens  
Bus Engine Sales  
Cummins Engine Company  
1900 McKinley Avenue  
Columbus, IN 47201  
812-377-7338

Vinod Duggal  
Director, Alternative Fuels Products  
Cummins Engine Company Inc.  
P.O. Box 3005  
Columbus, IN 47202  
812-377-7338

Tom Cummings  
Deere Power Systems Group  
3801 W. Ridgeway Ave.  
P.O. Box 5100  
Waterloo, IA 50704  
319-292-5220

Bill Horrell  
Deere Power Systems Group  
3801 W. Ridgeway Ave.  
P.O. Box 5100  
Waterloo, IA 50704  
319-292-8629

Randy Swanson  
Product/Market Manager  
Deere Power Systems Group  
3801 W. Ridgeway Ave.  
P.O. Box 5100  
Waterloo, IA 50704  
319-292-5348

Nancy Martin  
Editor, Newsletter of Alternative Fuels  
Detroit Diesel Corporation  
13400 Outer Drive, West  
Detroit, MI 48239  
313-592-5153

John Fisher  
Manager, Certification  
Detroit Diesel Corporation  
13400 Outer Drive, West  
Detroit, MI 48239  
313-592-7090

Jerry Hunt  
Product Support Manager  
Detroit Diesel Corporation  
P.O. Box 1229  
2808 San Ardo  
Belmont, CA 94002  
415-593-6263

Peter Hubbard  
Ford Motor Company  
Section Supervisor  
Powertrain Planning & Engineering  
11916 Market St.  
Livonia, MI 48150  
313-591-7505

Tom Steckel  
Marketing  
Ford Motor Company  
Dearborn, MI 48121  
313-323-9867

Carl Chorba  
Regional Sales Manager,  
Western Region  
Ford Motor Company  
Truck Operations  
P.O. Box 9048  
Pleasanton, CA 94566  
510-942-8072

Kim Boyer  
Hercules Engine Company  
101 - 11th Street, S.E.  
Canton, OH 44707  
216-438-1361

Kevin Flaherty  
Mack Trucks Inc.  
2100 Mack Blvd., Box M  
Allentown, PA 18105  
215-439-3815

Thomas Trueblood  
Manager, Public Affairs International  
Navistar International Transp. Corp.  
455 N. Cityfront Drive  
Chicago, IL 60611  
708-836-2646

Dr. Pranab K. Das  
Manager, Engine Technology  
Navistar International Transp. Corp.  
10400 W. North Ave.  
Melrose Park, IL 60160  
708-865-3356

Warren Slodowske  
Manager, Environmental Staff  
Manager, Engine Technology  
Navistar International Transp. Corp.  
10400 W. North Ave.  
Melrose Park, IL 60160  
708-865-4200

Dr. Tze-Ning Chen  
Senior Program Manager  
Tecogen Inc.  
45 First Ave.  
P.O. Box 8995  
Waltham, MA 02254  
617-622-1400

Michael Koplow  
Director, Engine Technology  
Tecogen Inc.  
45 First Ave.  
P.O. Box 8995  
Waltham, MA 02254  
617-622-1303

## Government

California Energy Commission  
Transportation Technology & Fuels Office  
Heavy-Duty Demonstration Program  
1516 Ninth Street, MS-41  
Sacramento, CA 95814  
916-654-4634

Ruth Anne Keister  
Clean Cities Hotline  
P.O. Box 12316  
Arlington, VA 22209  
1-800-C-CITIES

George Karbowski  
Alternative Fuels Supervisor  
Metropolitan Transportation Authority  
900 Lyon Street  
Los Angeles, CA 90012  
213-291-5866

Toros Topaloglu  
Ministry of Transportation of Ontario  
1201 Wilson Avenue  
Downstream, Ontario  
CANADA M3M 1J8  
416-235-5017

Linda Bluestein  
Contract Manager  
National Alternative Fuels Hotline  
P.O. Box 12316  
Arlington, VA 22209  
800-423-1DOE (1363)

Steve Goguen  
Office of Alternative Fuels  
Transit Bus Pgm.  
U.S. Department of Energy  
1000 Independence Ave., S.W.  
Room 5G086  
Washington, DC 20585  
202-586-8044

Steve Barsony  
Federal Transit Administration  
U.S. Department of Transportation  
400 - 7th Street, S.W.  
Room 6423  
Washington, DC 20590  
202-366-0090

Vincent Demarco  
Local Transit Authorities Alternative Fuel  
Initiative Program  
Federal Transit Administration  
U.S. Department of Transportation  
400 7th Street, S.W., Room 6423  
Washington, DC 20590  
202-366-0090

Bill Blessing  
Intermodal Surface Efficient  
Transportation Act  
Federal Transit Administration  
U.S. Department of Transportation  
400 - 7th Street, S.W., Room 6423  
Washington, DC 20590  
202-366-0690

Donna Billinger  
Intermodal Surface Efficient  
Transportation Act  
U.S. Department of Transportation  
400 - 7th Street, S.W.  
Washington, DC 20590  
202-366-0690

Mike Savonis  
Congestion Mitigation & Air Quality  
(CMAQ) Improvement Program Funds  
U.S. Department of Transportation  
400 - 7th Street, S.W.  
Washington, DC 20590  
202-366-2080

Shiang Hsiung  
Federal Transit Administration  
U.S. Department of Transportation  
400 - 7th Street, S.W., Room 6423  
Washington, DC 20590  
202-366-0090

Tom Baines  
National Vehicle  
& Fuel Emissions Laboratory  
U.S. Environmental Protection Agency  
2565 Plymouth Road  
Ann Arbor, MI 48105  
313-668-4366

Phil Carlson  
National Vehicle  
& Fuel Emissions Laboratory  
U.S. Environmental Protection Agency  
2565 Plymouth Road  
Ann Arbor, MI 48105  
313-668-4366

Rick Rykowski  
National Vehicle  
& Fuel Emissions Laboratory  
U.S. Environmental Protection Agency  
2565 Plymouth Road  
Ann Arbor, MI 48105  
313-668-4339

Ginny Hobbs-Moore  
CNG & LNG Research Programs  
Gas Research Institute  
8600 Bryn Mawr Avenue  
Chicago, IL 60631  
312-399-8100

Norm Yale  
Project Manager  
Gas Research Institute  
8600 W. Bryn Mawr Avenue  
Chicago, IL 60631  
312-399-5414

Heavy-Duty Representatives Association  
4015 Marks Road, Suite 2B  
Medina, OH 44256  
216-725-7160

Susan Volek  
Assistant Vice President  
SAIC - Science Applications  
International Corp  
4242 Campus Point Court, M/S D-7  
San Diego, CA 92121  
619-535-7286

## Organizations

American Bus Association  
1100 New York Ave., N.W.,  
Suite 1050  
Washington, DC 20005  
202-842-1645

Tim McGrath  
Trucking Research Institute  
American Trucking Association  
2200 Mill Road  
Alexandria, VA 22314  
703-838-1966

Glenn F. Keller  
Executive Director  
Engine Manufacturers Association  
401 North Michigan  
Chicago, IL 60611-4267  
312-527-6610



# Chapter 9

## Other Alternative & Clean Fuels

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Other alternative fuels may hold promise for future use. These include biodiesels, hydrogen (in both fuel cells and internal combustion engines), liquefied natural gas, etc. More research, however, is needed and these fuels need to be proven in demonstration programs, infrastructure developed, etc. before they can become widely used. Many hurdles will have to be overcome for some of these fuels. But most Californians will be using a cleaner fuel beginning June 1, 1996. It's called ARB Phase 2 Reformulated Gasoline. This chapter will look at some of the other alternatives and finish with a look at reformulated gasoline or RFG.

### Biodiesel

Biodiesel is the name for a variety of diesel fuel alternatives based on methyl esters of vegetable oil or fats. It fits under the category of a renewable fuel because it is made from agricultural feedstocks such as soybean or rapeseed. Research on soy-based diesel is taking place in the United States, while European countries have been focusing on rapeseed derived biodiesel. Other possible feedstocks for biodiesel include bio-oils from corn, cottonseed, peanut, sunflower, canola, and rendered tallow (animal fat). The National Renewable Energy Laboratory is testing aquatic plants, such as microalgae, for possible lipid (oil) production.

The fuel is made by a catalytic chemical process called trans-esterification, using an alcohol (such as methanol) and a catalyst. Methanol is mixed with sodium hydroxide and then with soybean oil, letting the glycerine, that is formed, to settle. This forms fatty esters which are then separated into two phases, which allows easy removal of glycerol in the first phase. The remaining alcohol/ester mixture called methyl soyate is then separated and the excess alcohol is recycled. The esters are sent to the clean-up or purification processes which consists of water washing, vacuum drying and filtration.

The final fuel closely resembles conventional diesel fuel, with higher cetane number (a number that rates its starting ability and antiknock properties). Energy

content, viscosity and phase changes are similar to petroleum-based diesel fuel. The fuel is typically blended with 20 percent low-sulfur diesel fuel.

The fuel is essentially sulfur free, emits significantly less particulates, hydrocarbons and carbon monoxide. Nitrogen oxides emissions (NOx) are similar to diesel and can be kept in check with catalytic converter technology. Biodiesel has a high flash point and has very low toxicity if digested. It is also biodegradable.

The biggest drawback of biodiesel is cost. The cost of the fuel is determined by the feedstock being used, but is estimated at approximately today at \$2.50 to \$6.00 a gallon because of the small-scale production. The U.S. Departments of Energy and Agriculture have estimated that large-scale production using today's technology could reduce biodiesel costs to \$1.50 to \$1.60 a gallon. And biodiesel from microalgae may cost as low as \$1.00 a gallon.

Another drawback is that vehicle fuel lines and other components that would come in contact with the fuel would have to be changed because biodiesel can dissolve rubber. The fuel also clouds and stops flowing at higher temperatures than diesel, so fuel-heating systems or blends with diesel fuel would be needed in lower temperature climates.

In Europe, biodiesel use (blended with diesel) is growing because the price of petroleum fuel is three to four times what it is in the United States. According to the London *Daily Mail*, the price in December 1994 for Shell unleaded petrol in Britain was 240.5 pence a gallon or \$3.92 U.S. per gallon (with the exchange rate at 100 pence or one (1) pound = \$1.63 U.S.). In Holland the price is 309.13p a gallon (\$5.04 per gallon); in France it is 291.4p a gallon (\$4.75 per gallon) and in Germany it costs 386.85p a gallon (\$6.31 a gallon). So, biodiesel can compete well with petroleum products in Europe.

According to *The Irish Times*, Ireland is looking at converting a portion of land to production of biodiesel feedstock. According to Pat Bell of the Irish Energy Centre, "There are currently 36,000 hectares of land under the set-aside system in Ireland. Only 1,000 hectares are being used to produce oil seed. The other 35,000 hectares are lying idle when they could be producing 30,000 tonnes of seed oil and returning a

profit for their owners.”

The article says that currently biodiesel produced from rapeseed is up to 20 pence a liter more expensive (\$0.33 U.S. per liter or \$1.24 U.S. per gallon) than ordinary diesel at the pumps. But the cost to produce biodiesel is expected to come down when production increases.

Biodiesel seems to be growing in popularity and people are looking to covert vehicles to using the alternative fuel. The London *Daily Mail* in its December 3, 1994, edition said that biodiesel conversion kits for Volkswagen Golf and Vento cars will be on sale within a year in England.

Research activities are underway in the U.S. to use biodiesel, especially for urban transit. Research is being sponsored by the U.S. Environmental Protection Agency and the U.S. Departments of Agriculture and Energy, as well as other private organizations, state and local government. Research has been conducted for both light-duty and heavy-duty applications (see list below).

And biodiesel seems to be gaining popularity with transit managers compared to other alternative fuels, according to a story in *Urban Transport News*. A recent survey shows that biodiesel ranks second behind compressed natural gas in popularity.

One-fifth of transit managers surveyed by St. Louis-based Fleishman-Hillard Research, in a survey for the National Biodiesel Board, rank biodiesel as the top choice alternative fuel for transit buses. One in six transit managers expects to use biodiesel over the next two years, the survey found.

“Biodiesel is gaining attention because it offers significant emissions reductions with no modifications to bus engines and transit infrastructures,” said Kenlon Johannes, executive director of the National Biodiesel Board (NBB). NBB, which promotes and researches soy-based biodiesel, is funded by the United Soybean Board. Awareness of biodiesel has nearly tripled in the last two years, the survey found.

According to *Urban Transport News*, survey respondents most frequently mention smoke reduction and the fact that biodiesel does not require engine alterations as primary advantages of the fuel.

Much more needs to be demonstrated before biodiesel can be a fuel for vehicle use in the United States, and the price needs to become much more competitive with diesel.

### Some Early Biodiesel Demonstration Programs in the United States

<i>Location</i>	<i>Research Done By</i>	<i>Vehicle</i>	<i>Purpose</i>
Columbia, MO	Univ of Missouri	3/4-ton truck	Emissions, power
Columbia, MO	Phil Blom	Heavy-duty tractor	General
Jefferson City, MO	Missouri Soy Assn.	3/4-ton truck	General
Kansas City, MO	Interchem	Toyota Camry	General
St. Louis, MO	City of St. Louis	100 vehicles	Emissions, general
St. Louis, MO	Mass Transit	47 transit buses	Emissions
Sioux Falls, SD	Mass Transit	2 transit buses	Emissions
State of Illinois	Dept. of Trans.	2 Light-duty + 6 snowplows	General
City of Gardena, CA	Municipal Bus Lines	2 transit buses	Emissions

## Hydrogen

Hydrogen is the most abundant element in the universe, but is rarely found in its uncombined form on the earth. When combusted (oxidized) it creates only water vapor as a by-product ( $4\text{H} + \text{O}_2 = 2\text{H}_2\text{O}$ ). When burned in an internal combustion engine, however, combustion also produces small amounts of nitrogen oxides and small amounts of unburned hydrocarbons and carbon monoxide because of engine lubricants. The exhaust is free from carbon dioxide.

Hydrogen is normally a gas and can be compressed and stored in cylinders. It can also be kept as a liquid, but the gas only turns liquid at temperatures of minus 423.2 degrees Fahrenheit (**below zero**)!

Today, hydrogen is mostly obtained by cracking hydrocarbon fuels, but it can be produced by electrolysis of water (using electricity to split water into hydrogen and oxygen) and photolysis (chemical decomposition).

The main problem with hydrogen is bulk storage required for fuel tanks. For an equivalent energy content of gasoline, liquid hydrogen and the required refrigeration system requires six to eight times more storage space than gasoline and compressed hydrogen gas requires six to ten times more storage space.

Automobile manufacturers have experimented with hydrogen as a fuel. Research vehicles have been produced by Daimler-Benz, BMW and Mazda. The Mercedes-Benz and BMW vehicles use liquid hydrogen. The Mazda vehicle stores its hydrogen as a gas in a metal-hydride lattice of shaved metal. Other vehicles have been built using compressed hydrogen, including two vehicles in Arizona operated by the American Hydrogen Association.

In California, Xerox® Corporation, with funding from the U.S. Department of Defense, demonstrated a solar-powered photovoltaic (PV) hydrogen fuel generating facility. The hydrogen was to be used in a small demonstration fleet of vehicles. The cost of a 33 kilowatt PV-hydro production facility was estimated at \$1.4 million and could service five vehicles.

Also in California, Riverside Community College has been producing hydrogen via electrolysis for two service vehicles (light-duty pickup trucks). The hydrogen is compressed in cylinder/tanks and gives the pickups a range of 10 to 25 miles before needing to be refilled. This is adequate for the on-campus use of the vehicles. The college has also been training students in automotive maintenance and vehicle retrofits with an emphasis on hydrogen vehicles and engines. The College is also working with the University of California, Riverside's College of Engineering for

additional demonstration of hydrogen-powered vehicles.

Another development using hydrogen is as a blend of hydrogen and methane (natural gas) called Hythane. Preliminary information presented in mid-1994 at the 10th World Hydrogen Energy Conference in Cocoa Beach, Florida, says that a test car's exhaust using 30 percent hydrogen and 70 percent methane contained 80 percent less nitrogen oxides than U.S. EPA standards for 2003. This blend has much higher content of hydrogen than other Hythane blends, which typically run about five percent.

Although hydrogen has a higher energy content than gasoline or diesel fuel, high production costs and low density have prevented its use as a transportation fuel in all but test programs, and it may never be cost-competitive with other fuels. It maybe 20 to 30 years or more before hydrogen is a viable transportation fuel and then perhaps only in fuel-cell-powered vehicles.

## Fuel-Cells

Fuel cells are used to provide power on manned space flights, and the technology could come "down to earth" to run automotive motors in electric vehicles. By chemically combining — rather than burning — hydrogen and oxygen, electricity and water vapor are created as a by-product. Today's fuel cells are too bulky and costly, but promising new concepts are under development that would shrink both their size and price tag. And we could see practical fuel cells in use on vehicles in the next 10 to 20 years.

The fuel cell power system involves three basic steps. First, methanol, natural gas or another fuel containing hydrogen reacts with steam or is reformed to produce hydrogen. This hydrogen is then electrochemically combined with oxygen in the fuel cell.

Fuel cells operate like a battery. Hydrogen and air are fed to the anode and cathode, respectively, of each cell. These cells are stacked to make up the fuel cell stack. As the hydrogen diffuses through the anode, electrons are stripped off, creating direct current electricity. This electricity can be used directly in a DC electric motor or can be converted to alternating current.

Since the methanol or natural gas fuel is not burned, there is little or no pollution from the generation of electricity.

Fuel cells were first used in the space program. These units, based on an alkaline electrolyte, use pure hydrogen and oxygen stored as liquids on board the

space craft. Another form of fuel cell uses phosphoric acid as an electrolyte to produce electricity and hot water. The South Coast Air Quality Management District (SCAQMD) has a stationary phosphoric acid fuel cell producing electricity for its headquarters in Diamond Bar, Calif.

Another more advanced type of fuel cell is called a molten carbonate fuel cell and uses carbonate salts, which provide increased electrical efficiency over the earlier concepts. These operate at an elevated temperature and produces steam instead of hot water.

The world's largest molten carbonate fuel cell (MCFC) stationary power plant, which promises nearly pollution-free electrical generation, was unveiled in 1994 at Unocal Corporation's research center in Brea, Calif. The 250-kilowatt power plant was designed and built by M-C Power Corporation and its team members. The commercial demonstration project is being underwritten by the U.S. Department of Energy (DOE), Gas Research Institute (GRI), Electric Power Research Institute (EPRI), SCAQMD, Southern California Edison, Southern California Gas Company and the State of Illinois.

The fuel cell technology that seems to have the greatest use in vehicles is called the proton exchange membrane (PEM). This fuel cell is lighter than other types but basically works in the same manner.

At least two North American companies are working on fuel-cell powered buses. Ballard Power Systems Incorporated of North Vancouver, British Columbia, is the developer of a PEM fuel cell that converts hydrogen, natural gas or methanol fuel into electricity without combustion. It is working with Daimler-Benz, General Motors and the Dow Chemical Co. to develop fuel cell vehicles and stationary power plants. Ballard has already created a 120 kilowatt/hour, 20-passenger fuel-cell bus using stored, compressed hydrogen. The bus is undergoing testing by BC Transit. Ballard is also working on a full-size transit bus using methanol or natural gas as the "feedstock" to produce hydrogen for the fuel cell.

Another prototype bus is part of an effort by H Power, a Santa Barbara, Calif., bus manufacturer, and the U.S. Department of Energy to place the quiet and little-used fuel-cell technology beneath the hoods of buses, trucks and cars across the country by the end of the decade. H Power uses methanol in its fuel cell stack. The company started working with buses because the power packs are currently too large for most passenger cars.

A Society of Automotive Engineers report says that using 650 pounds of liquid hydrogen can power a full-size electric transit bus for 3,000 miles. Such a bus

would use a 150 kilowatt fuel cell at 55 to 65 percent efficiency.

## Hybrid Vehicles

Hybrid electric vehicles (HEVs or "hybrids" for short) are basically electric vehicles that use something other than a battery as another energy source. Typically, the vehicle has a liquid or gaseous fuel-powered generator that runs at constant speeds to produce electricity to power the vehicle and usually to charge its batteries.

Hybrids allow EVs to have extended range, going further than a vehicle can travel on just the charge in its batteries. Being a hybrid would allow the vehicle to operate on only batteries within an urban/polluted area, and then switch to its turbine/generator outside the urban area. Such a hybrid can get 80 or more miles per gallon because the constant speed generator can be made to be very fuel efficient. The HEV also doesn't normally require recharging from an outboard power source.

The vehicle's generator can be a gas turbine engine, which is widely used in power generation plants. It is highly efficient, but only when run at a constant speed. A typical automobile generator may operate at speeds ranging from 1,000 to 7,500 rpm or higher.

A gas turbine generator is being designed for the Volvo Environmental Concept Car (see electric vehicle chapter).

All of the "Big Three" auto companies are working with the U.S. Department of Energy on independent hybrid electric vehicle programs. As part of the Clinton administration's "supercar" program, Ford announced, in 1994, a \$122 million federal contract to design a hybrid within five years. GM is also working on developing a hybrid EV under the program. Chrysler is also looking at tomorrow's "supercar."

According to an article in the *Washington Times*, "The Big Three not only have to imagine this Supercar, they have to build it as part of the Partnership for a New Generation Vehicle. The billion-dollar consortium was created in 1994 as part of a deal with the Clinton White House...meeting the mandates of the PNGV, which is dubbed the Supercar program, will require technological breakthroughs in virtually every aspect of automotive design and engineering...."

"So far, the consortium has targeted 16 high-priority research projects, though dozens of other ideas are under investigation. They fall into four basic categories: 1) Energy conversion (search for a new power source); 2) Energy storage; 3) Electrical and electronics; and 4) Mass reduction (lighter vehicles)."

## Solar-Powered Vehicles

We probably won't be able to harness the sun's rays to power our regular vehicles. For one thing, current photovoltaic (PV) cells are too inefficient. Even state-of-the-art PV cells only get up to around 20 percent efficiency. And you would need a large area of cells to create even a small amount of electricity. The PV cells used on the solar-powered "race cars" measure two meters by ten meters and produce only about 1,500 to 2,000 watts of electricity...about enough to power a blow-dryer for hair. That's the size of the PV panels used by the world's oldest solar car race, The World Solar Challenge from Perth to Sydney, Australia. These cars are also impractical, single seaters that weigh less than 400 to 500 pounds, including driver.

According to a report on *Alternative Energy Network Online Today*, from November 16, 1994, "The solar-powered Aurora Q1 broke Australia's trans-continental record last week by crossing 2,485 miles from Perth to Sydney in 8 days — cutting the previous solar car record trip of 20 days by more than one-half. The 2,485 mile trip was sponsored by electronics and computer shop entrepreneur Dick Smith, owner of Australian Geographic magazine, with 60 businesses financing the \$375,000 design and construction of the vehicle.

"The Aurora Q1 averaged 31 miles per hour on its journey. Smith and the Aurora team point out that the vehicle did not use the most efficient solar cells that are currently available, so the speed for future trips will be further increased. In the future, Smith believes, the role of solar panels in vehicles will be expanded to charge the batteries used for the electric systems on conventional cars."

Smith is probably correct in his estimates. Solar panels will probably provide a "trickle charge" for electric vehicle's batteries. Or, they may power an EVs heating/air-conditioning system to warm or cool the interior of a vehicle while parked. Solar cell "charging ports" for EVs, however may be used to charge batteries. The Los Angeles Dept. of Water and Power and Sacramento Municipal Utility District are both using solar "charging ports" for their EVs.

## Reformulated Gasoline

### What is Reformulated Gasoline?

Reformulated gasoline (RFG) is a "cleaner-burning" gasoline that will significantly improve air quality by reducing emissions from all gasoline-burning motor vehicles and engines. RFG is required by U.S. Environmental Protection Agency (U.S. EPA) and California Air Resources Board (ARB) regulations to help meet air quality standards.

Beginning January 1, 1995, federal law requires the use of "clean-burning" gasoline in the worst polluted areas of the nation, including Southern California. Starting in March 1996, state law requires the production of even "cleaner-burning" gasoline: "ARB" Phase 2 RFG. By June 1, 1996, all gasoline sold in California must be ARB Phase 2 RFG.

### Why Do We Need Phase 2 RFG in California?

California has severe air quality problems, and motor vehicles are the largest contributors. Motor vehicles account for about one-half of the emissions of volatile organic compounds (VOCs) and oxides of nitrogen (NOx), which contribute to the formation of ozone – the main ingredient in smog.

### What are the Benefits of Phase 2 RFG?

**Clean Air** – Phase 2 RFG will immediately reduce emissions from all existing on-road gasoline-burning cars and trucks. It will produce the largest emissions reduction of any control measure to date. Reductions from vehicular emissions in 1996 are estimated to be:

<b>California Phase 2 RFG Emission Reductions</b>	
<i>Compound</i>	<i>Estimated Reduction</i>
Volatile Organic Compounds	17% (190 tons/day)
Oxides of Nitrogen	11% (110 tons/day)
Sulfur Dioxide	80% (30 tons/day)
Carbon Monoxide	11% (1,300 ton/day)

**Reduced Cancer Risk** – ARB Phase 2 RFG will also reduce emissions of cancer-causing pollutants. These reductions translate into approximately a 40 percent decrease in the cancer risk due to gasoline-powered motor vehicles.

**More Jobs** – Gasoline producers will need to modify their refineries, creating 20,000 temporary construction and several hundred permanent jobs.

**Clean Cars** – Auto manufacturers will use Phase 2 RFG (and alternative fuels) to meet California's stringent low-emission vehicle regulations.

Reformulated gasolines will be cleaner for the environment and will help cut air pollution. They are not, however, alternative fuels as recognized by the National Energy Policy Act and by the California Energy Commission. And because they are petroleum-based, they will continue to keep us dependent on only one source for our transportation needs, unless we begin to use other **alternative fuels**.

For more information about reformulated gasoline, contact:

California Air Resources Board  
Public Information Office  
(916) 322-2990

## Into the Future...

As we move into the 21st Century, there will be other storage devices, fuels and vehicles in our distant future that have yet to be utilized, invented or discovered. Certainly, we will have to decrease our dependence on petroleum, if only because we have an estimated 60 years of oil resources left with today's known reserves.

Technologies such as ultra-capacitors, superconducting magnets, flywheels and other esoteric technologies may one day provide power storage for our vehicles. We will also see vehicles that get much higher mileage than the vehicles being used in the mid-1990s as engine efficiency levels increase and vehicle become lighter, using space-age composites and aerospace/defense industry materials.

In 1996, the California Energy Commission will publish the third edition of its *Energy Technologies Status Report*. This comprehensive report lists every known energy technology, its current status in development or usage, barriers to implementation of the technology and other information. The third edition will include a separate volume on transportation technologies and should give a good over-all discussion of each and every technology currently known.

*You will always underestimate the future.*  
– Charles F. Kettering

### Reformulated Gasoline Milestones

California Phase 1 RFG implemented .....	January 1992
California Wintertime Oxygenated Program .....	November 1992
Federal Phase 1 RFG (Southern California only) .....	January 1995
California Phase 2 RFG Testing Program* .....	Feb – Aug 1995
California Phase 2 RFG implementation	
Refineries .....	March 1, 1996
Terminals .....	April 15, 1996
Service Stations .....	June 1, 1996

\* The California RFG Testing Program evaluates the effects of fuels on more than 1,000 vehicles, and on power and lawn tools and other equipment.

## Biodiesel Contacts

### Government

John V. Rosania, Jr.  
Connecticut Transit  
Hartford Division  
100 Leibert Road  
Hartford, CT 01641-0066  
203-522-8101

Noni Strawn or Norm Hinman  
Biofuels Information Center  
National Renewable Energy  
Laboratory  
1610 Cole Blvd.  
Golden, CO 80401-3393  
303-231-1947 or 303-231-1281

Janet Cushman  
Biomass Prgm.  
Short Rotation Woody Crops  
Oak Ridge National Laboratory  
P.O. Box 20008  
Oak Ridge, TN 37831  
615-574-7377

Dick Auld  
Agronomy Department  
Texas Technical University  
P.O. Box 42122  
Lovit, TX 79408  
806-742-2838

John McClelland  
U.S. Department of Agriculture  
Office of Energy  
1301 New York Ave., N.W.,  
Room 1208  
Washington, DC 20005  
202-219-1941

John Ferrell  
Program Manager  
U.S. Department of Energy  
1000 Independence Ave., S.W.  
Washington, DC 20585  
202-586-6745

Charles L. Peterson  
University of Idaho  
Dept. of Agricultural Engineering  
Moscow, ID 83844  
205-885-6182

### Organizations

Bill Homberg  
President  
American Biofuels Association  
1925 N. Lynn Street, Suite 1050  
Arlington, VA 22209  
202-522-3392

Jeff Beller and Julia Delain  
Biofuels America  
RD 1, Box 19  
Westerlo, NY 12193-9801  
518-797-3377

Kenlon Johannes  
Executive Director  
National SoyDiesel Development  
Board  
P.O. Box 104898  
107 Williams Street  
Jefferson City, MO 65110  
314-635-3893 or  
toll free 800- 841-5849

Tom Ryan  
Southwest Research Institute  
6220 Culebra Road  
P.O. Drawer 28510  
San Antonio, TX 78228  
512-522-3192

Sustainable Farming  
REAP - Canada  
Box 125, Glenaladale House  
Ste. Anne de Bellevue, Quebec  
CANADA H9X 1C0  
514-398-7743

United Soybean Board  
16305 Swingley Ridge Dr., Suite 110  
Chesterfield, MO 63107  
314-530-1777

## Hydrogen Contacts

Chuck Mizutani  
Technology Evaluation Office  
California Energy Commission  
Energy Technology Development Division  
1516 Ninth Street, MS-43  
Sacramento, CA 95814  
916-654-4636

Dr. Robert Zweig  
2936 McAllister Street  
Riverside, CA 92503  
714-688-5474

Roy McAllister  
American Hydrogen Association  
216 South Clark Street, MS-103  
Tempe, AZ 85281  
602-921-0433

David E. Bruderly  
Bruderly Engineering Associates  
1826 N.W. 57th Terrace  
Gainesville, FL 32065  
904-377-0932

Greg Egan  
Hydrogen Consult. Inc.  
12420 N. Dumont Wy.  
Littleton, CO 80125

Peter Hoffman  
Editor  
Hydrogen Letter  
4104 Jefferson Street  
Hyattsville, MD 20781  
301-779-1561

Debbi L. Smith  
National Hydrogen Association  
1101 Connecticut Avenue, N.W.,  
Suite 910  
Washington, DC 20036  
202-223-5547

Carl Helman or Ron Schaeffer  
National Vehicle  
& Fuel Emissions Laboratory  
U.S. Environmental Protection Agency  
2565 Plymouth Road  
Ann Arbor, MI 48105  
313-668-4246 or 313-668-4279

Steve Rubin  
National Renewable Energy Laboratory  
1617 Cole Blvd.  
Golden, CO 80401-3393  
303-275-4065

David Swan  
University of California, Davis  
Davis, CA 95616  
916-752-7434

Dr. Joseph Norbeck  
College of Engineering – Center for  
Environmental Research and  
Technology (CE-CERT)  
University of California, Riverside  
Riverside, CA 92521

Susan Sullivan  
Office of University Relations  
University of California, Riverside  
Riverside, CA 92351  
909-787-5893

Michael Gurevich  
Program Manager  
U.S. Department of Energy  
1000 Independence Ave., S.W.  
Washington, DC 20585  
202-586-6104

## Fuel Cell Contacts

Ed Gillis  
American Association for fuel Cells  
A Project of Clean Air Revival, Inc.  
50 San Miguel Avenue  
Daly City, CA 94105

Editor  
Fuel Cell News  
American Fuel Cells Association  
P.O. Box 65482  
Washington, DC 20035  
301-681-3532

Martin Gutstein  
American Fuel Cells Association  
P.O. Box 65482  
Washington, DC 20035  
301-681-3532

Roy McAllister  
American Hydrogen Association  
216 South Clark Street, MS-103  
Tempe, AZ 85281  
602-921-0433

Geoffrey Ballard  
Chairman  
Ballard Power Systems  
107 - 980 West 1st Street  
Vancouver, British Columbia  
CANADA V7P 3N4  
604-986-9367

Martin Gutstein  
Fuel Cells Institute  
P.O. Box 65481  
Washington, DC 20035  
301-681-3532

Peter Hoffman  
Editor  
Hydrogen Letter  
4104 Jefferson Street  
Hyattsville, MD 20781  
301-779-1561

Debbi L. Smith  
National Hydrogen Association  
1101 Connecticut Avenue, N.W.,  
Suite 910  
Washington, DC 20036  
202-223-5547

Steve Rubin  
National Renewable Energy  
Laboratory  
1617 Cole Blvd.  
Golden, CO 80401  
303-231-1365

Susan Volek  
Assistant Vice President  
SAIC - Science Applications  
International Corp  
4242 Campus Point Court, M/S D-7  
San Diego, CA 92121  
619-535-7286

David Swan  
University of California, Davis  
Davis, CA 95616  
916-752-7434

Dr. Joseph Norbeck  
College of Engineering – Center for  
Environmental Research and  
Technology (CE-CERT)  
University of California, Riverside  
Riverside, CA 92521

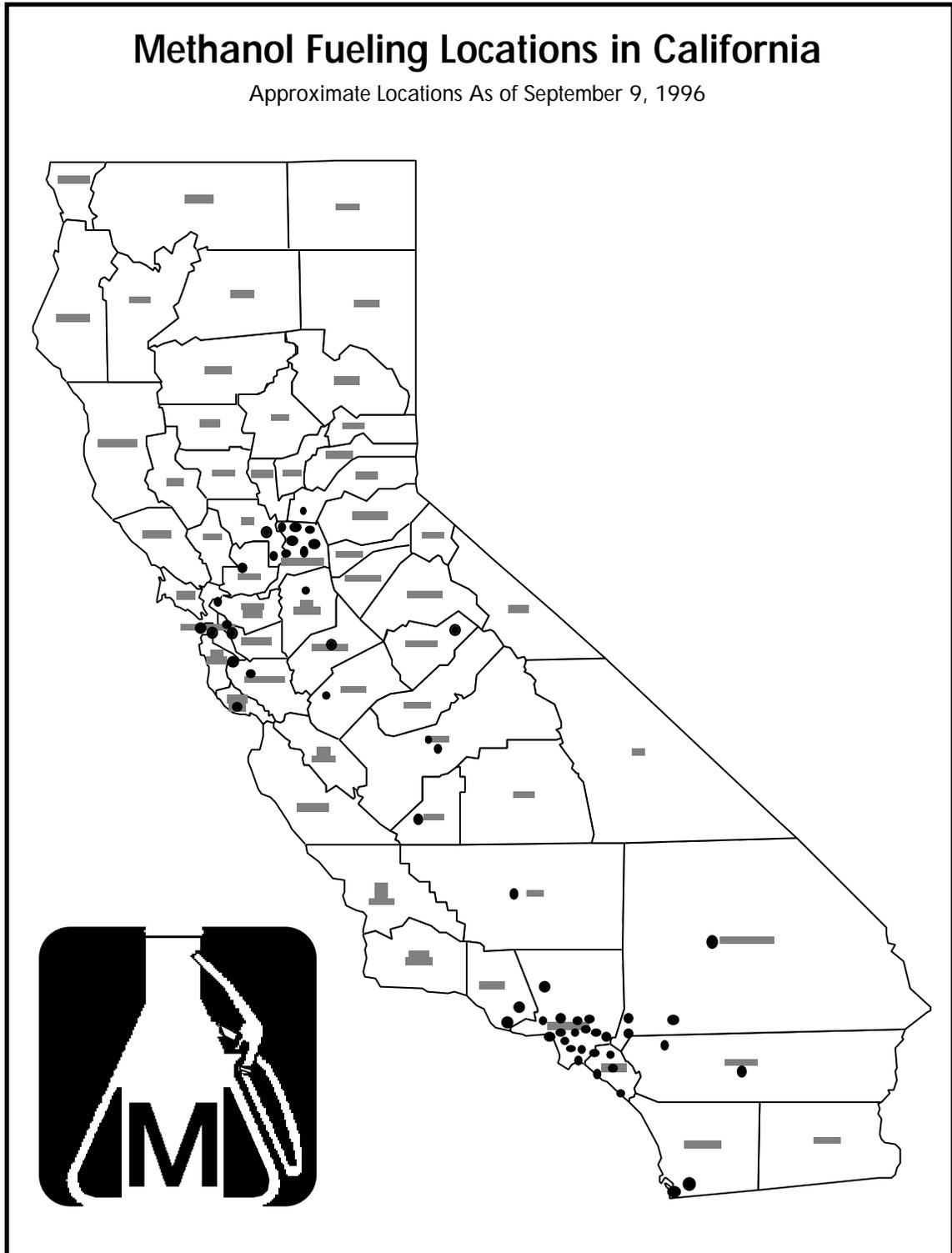
Susan Sullivan  
Office of University Relations  
University of California, Riverside  
Riverside, CA 92351  
909-787-5893

Pandit Patil  
Program Manager, Propulsion Office  
U.S. Department of Energy  
1000 Independence Avenue, S.W.  
Washington, DC 20585  
202-586-8055

Carl Helman  
National Vehicle  
& Fuel Emissions Laboratory  
U.S. Environmental Protection Agency  
2565 Plymouth Road  
Ann Arbor, MI 48105  
313-668-4246

# Chapter 10

## Locations of Alternative Fuel Facilities





# Methanol Fueling Locations in California

(As of September 9, 1996)



## Northern California

### Cordelia

- Chevron (OPEN 11/96)
- 4490 Central Way

### Davis

- ARCO
- 705 Russell Blvd.

### Fresno

- Chevron
- 4161 East Ventura Ave.
- Texaco
- 3808 No. Blackstone Ave.

### Modesto

- SEMCO (OPEN 12/96)
- 1217 7th Street

### Oakland

- Chevron
- 451 Hegenberger Road
- PCI (OPEN 1/97)
- 2311 Magnolia Street

### Richmond

- Exxon
- 12678 San Pablo Ave.

### Roseville

- Exxon
- 1000 Douglas Blvd.

### Sacramento

- ARCO
- 2225 16th Street
- Chevron
- 3001 Zinfandel Drive  
(*Rancho Cordova*)
- Exxon
- 3430 Northgate Blvd.
- Shell
- 8607 Elk Grove Blvd.  
(*Elk Grove*)
- Shell
- 730 29th Street
- Shell
- 8090 Folsom Blvd.
- Ultramar
- 4250 Madison Avenue  
(*North Highlands*)

### San Francisco

- Shell
- 3035 Geary Street
- Olympian Oil Co.
- 2690 Third St.

### San Jose

- Exxon
- 890 Coleman Avenue

### Santa Cruz

- Chevron
- 404 Soquel Ave.

### Santa Nella

- Chevron
- 12801 Highway 33, South

### Stockton

- Chevron
- 2905 West Benjamin Holt

### Sunnyvale

- Exxon
- 696 El Camino Real

### Woodland

- Ramos Oil Co.
- 597 No. East Street

### Yosemite National Park

- Chevron
- Northside Drive

## Southern California

### Anaheim

- Chevron
- 1801 South Harbor Blvd.

### Bakersfield

- ARCO
- 4100 California Ave.

### Barstow

- ARCO
- 1251 East Main Street

### Brea

- Brea Auto Spa (OPEN 1/97)
- 1700 E. Lambert Rd.

### Coachella

- ARCO
- 48-055 Grapefruit Blvd.

### Culver City

- Shell
- 3801 No. Sepulveda Blvd.

### Diamond Bar

- Chevron
- 150 So. Diamond Bar Blvd.

### Glendale

- ARCO
- 3941 San Fernando Blvd.

### Huntington Beach

- Shell
- 19002 Magnolia St.

### Kettleman City

- Ultramar (Beacon)
- 33190 Hubert Way

### Long Beach

- ARCO
- 1785 Bellflower Blvd.

### Los Angeles

- ARCO
- 3675 Wilshire Blvd.
- Chevron
- 1600 W. Olympic Blvd.
- Shell
- 5657 Sunset Blvd.

### Norwalk

- Texaco
- 10710 Alondra Blvd.

### Northridge

- Shell
- 17000 Roscoe Blvd.

### Ontario

- ARCO
- 2430 South Euclid Ave.

### Paramount

- Shell
- 7512 Alondra Blvd.

### Pasadena

- Mobil
- 392 No. Lake Ave.

### Rancho Cucamonga

- Parallel Products (OPEN 1/97)
- 12281 Arrow Route

### Riverside

- Mobil
- 1147 University Avenue

### San Bernardino

- Shell
- 1973 Tippecanoe Ave.

### San Diego

- ARCO
- 3205 University Ave.
- Chevron
- 1221 11th Ave.

### San Juan Capistrano

- Shell
- 26571 Junipero Serra Rd.

### Santa Ana

- ARCO
- 3414 Main Street

### Santa Fe Springs

- Chevron
- 11426 East Telegraph Rd.

### Santa Monica

- Chevron
- 1732 Lincoln Blvd.

### Simi Valley

- ARCO
- 25 West Tierra Rejada Rd.

### Thousand Oaks

- GTE Corporation
- 112 Lakeview Canyon Road

### Upland

- Mobil
- 411 South Mountain Ave.

### Valencia

- Shell
- 24301 Valencia Blvd.

### Ventura

- ARCO
- 605 South Mills Road

### Woodland Hills

- Mobil
- 20101 Ventura Blvd.

### Yorba Linda

- City of Yorba Linda
- 4845 Casa Loma

Note: There are also about 50 private methanol fueling facilities in the state operated by Caltrans, private and public fleets, and school and transit districts that are not open to the public.



# Natural Gas Fueling Locations in California

(As of March 18, 1996, compiled by California Natural Gas Vehicle Coalition)



## Anaheim

- Anaheim HDQ (pub.)
- 1919 S. State College Bl.
- City of Anaheim (Imtd.)
- 517 S. Claudina St.
- Disneyland (pvt.)
- 1313 Harbor Bl.
- MESA-Anaheim (Imtd.)
- 1430 S. Anaheim

## Anderson

- Anderson Unified (pvt.)
- 1417 Ferry St.

## Auburn

- PG&E Service Center (pub.)
- 343 Sacramento St.

## Avenal

- Avenal State Prison (pvt.)

## Bakersfield

- PG&E Service Center (pub.)
- 4101 Wibble Road
- FleetStar (pub.)
- 3305 Gulf Street
- Kern High S.D. (pvt.)
- Kern High School

## Belmont

- PG&E Service Center (pub.)
- 1970 Industrial Way

## Buttonwillow

- Elk Hills Naval Reserve (pvt.)

## Carlsbad

- SDG&E Service Cntr. (Imtd.)
- 5016 Carlsbad Blvd.

## Chatsworth

- LAMTA (pvt.)
- 9201 Canoga

## Chico

- City of Chico Yard (Imtd.)

## Chula Vista

- Chula Vista Ed. Ctr. (Imtd.)
- 84 E. "J" St.
- MTDB (pvt.)
- 3650 Mai St.

## Clovis

- Clovis School (pub.)
- 1450 Herndon Ave.

## Compton

- SoCal Gas (pub.)
- 700 N. Long Beach Bl.

## Concord

- PG&E Service Center (pub.)
- 1030 Detroit Ave.
- U.S. Post Office (pvt.)
- 2121 Meridian Ave.

## Corona

- SoCal Gas (pub.)
- 414 W. Grand Ave.

## Coronado

- SDG&E (Imtd.)
- Alameda Blvd. & 2nd St.

## Covina

- SoCal Gas (pvt.)
- 534 Barranca Ave.

## Cupertino

- PG&E Service Center (pub.)
- 10900 N. Blaney Ave.

## Davis

- PG&E Service Center (pub.)
- 316 L Street
- PG&E Service Center (pub.)
- 1415 2nd St.
- Unitrans (pvt.)
- UC Davis Transit

## Diamond Bar

- So. Coast AQMD (Imtd.)
- 21685 E. Copley Dr.

## Downey

- SoCal Gas (pub.)
- 9240 E. Firestone Bl.

## El Cajon

- UNOCAL (pub.)
- 1090 W. Main St.

## Encinitas

- Shell (pub.)
- 160 Encinitas Blvd.

## Escondido

- Shell Oil (pub.)
- 780 W. El Norte Pkwy.
- SDG&E (Imtd.)
- 1623 Mission Rd.

## Fresno

- PG&E Service Center (pub.)
- 3224 East California
- City of Fresno (Imtd.)
- 2101 "G" St.
- City of Fresno (pub.)
- E St. and El Dorado St.
- Visa Petroleum (pub.)
- 2414 Monterey St.

## Garden Grove

- SoCal Gas (pub.)
- 12631 Monarch St.

## Gardena

- LA Unified SD (Imtd.)
- 18421 Hoover St.

## Glendale

- SoCal Gas (pub.)
- 5610 San Fernando Rd.

## Goleta

- Santa Barbara Pub. Works (Imtd.)
- 4330 Calle Real

## Grass Valley

- PG&E Service Cntr. (pub.)
- W. McKnight Way

## Hayward

- PG&E Service Center (pub.)
- 24300 Clawiter Road

## Huntington Beach

- U.S. Postal Service (Imtd.)
- 6771 Warner Ave.

## Industry

- LA Sanitation (Imtd.)
- 2800 Workman Mill Rd.
- UNOCAL (pub.)
- 948 So. Azusa Ave.

## Irvine

- City of Irvine (pub.)
- 15642 Sand Canyon Ave.
- Federal Express (pvt.)
- 18651 Von Karman Ave.

## Lancaster

- SoCal Gas (pub.)
- 670 Avenue L-8
- Edwards AFB (pvt.)

## La Puente

- UNOCAL (pub.)
- 948 S. Azusa

## Lemoore

- US Naval AS (pvt.)
- Trans. Div. Bldg.

## Livermore

- PG&E Training Facility (pvt.)
- 7205 National Dr.
- Lawrence Livermore Labs (pvt.)
- East Avenue

## Lompoc

- Lompoc Schools (pvt.)
- US AFB (pvt.)
- Vandenburg

## Long Beach

- Long Beach Gas Dept. (pub.)
- 2400 E. Spring St.
- Long Beach Gas Dept. (pub.)
- 400 W. Broadway
- Port/SERRF Plant (Imtd.)
- 120 Henry Ford Ave.
- El Dorado Parks & Rec (pub.)

## Los Angeles

- County of L.A. (pub.)
- 1100 N. Eastern Ave.
- Shell (pub.)
- 2424 E. Olympic Blvd.
- SoCal Gas (Imtd.)
- 3124 W. 36th St.
- UCLA (Imtd.)
- 1140 Veteran Ave.
- UPS (pvt.)
- 3000 E. Washington
- LAX United Airlines (Imtd.)
- 6020 Avion Dr.

## Merced

- PG&E (pub.)
- 3185 M Street

## Modesto

- WH Breshears (pub.)
- 428 Seventh St

## Montebello

- Chevron (pub.)
- 1500 Paramount Blvd.

## Monterey

- Ryan Ranch (Imtd.)
- 25 Ryan Ranch Rd.

## Moreno Valley

- Shell (pub.)
- 12441 Heacock

## Norwalk

- UNOCAL (pub.)
- 14960 Carmenita St.

## Oakland

- PG&E Service Cntr. (Imtd.)
- 4801 Oakport
- City of Oakland (Imtd.)
- 7101 Edgewater Drive

## Oceanside

- No. County Transit (pvt.)

## Ontario

- City of Ontario (pub.)
- 14235 S. Bon View Ave.
- Whirlpool-Ontario (pvt.)
- 2151 Vintage

## Oroville

- City Corp. Yard (Imtd.)
- 1275 Mitchell Ave.
- Butte County Yard (Imtd.)
- 9 County Center Dr.

## Otay Mesa

- Texaco
- 2435 Otay Center Dr.

## Oxnard

- US Naval AS (pvt.)
- Point Magu
- 1650 Mountain View Ave.
- McValley Oil Co. (pub.)
- 100 N. Del Norte Bl.
- SoCal Gas (pub.)
- 1600 Patton Ct.

## Palo Alto

- City of Palo Alto (pvt.)
- 3201 E. Bayshore Rd.

## Paradise

- City Yard (Imtd.)
- 806 Cedar St.

## Paramount

- Braun Linen (pvt.)
- 16514 S. Garfield

## Pasadena

- Morrow & Hoffman (pvt.)
- 266 Monterey Rd.
- Dydee Diaper Co. (pvt.)
- 40 E. California Bl.

## Perris

- March AFB (pvt.)
- 15055 Hwy. 395

## Pico Rivera

- Northrup Corp. (pvt.)
- 8900 E. Washington
- SoCal Gas (pub.)
- 8101 S. Rosemead Bl.

## Port Hueneme

- US Navy (pvt.)

## Poway

- Poway School Dist. (Imtd.)
- 13626 Twin Peaks Rd.

## Rancho Cucamonga

- SBVVV (pub.)
- 12672 4th St.

## Richmond

- PG&E Service Center (pub.)
- 1100 South 27th St.

## Ridgecrest

- China Lake NAWs (pvt.)

## Riverdale

- Riverdale School Trans. (pvt.)
- 20900 Hazel

– more –



# Natural Gas Fueling Locations in California (contd.)

(As of March 18, 1996, information provided by California Natural Gas Vehicle Coalition)



## Riverside

- Riverside Transit (pvt.)  
1825 3rd St.
- UC Riverside (Imtd.)  
3401 Watkins Dr.
- SoCal Gas (pub.)  
4495 Howard Ave.

## Sacramento

- PG&E (Imtd.)  
Front & "T" Streets
- PG&E (Imtd.)  
5555 Florin-Perkins
- Sacramento Airport (pub.)  
7001 Airport Bl.
- Sacramento RT (pvt.)  
1400 29th St.
- Olympian Oil (pub.)  
4420 Northgate Bl.
- Interstate Oil (pub.)  
8221 Alpine Ave.

## Salinas

- PG&E (Imtd.)  
390 Griffin St.
- Monterey County (pvt.)  
County Yard

## San Bernardino

- County of San Bern. (pub.)  
210 N. Lena Rd.

## San Diego

- Mobil Oil (pub.)  
12849 Rancho Penasquitos Bl.
- San Diego Transit (Pvt.)  
• SDG&E (pub.)  
6875 Consolidated Way
- SDG&E (Imtd.)  
175 11th Ave.
- SDG&E (pub.)  
5488 Overland Ave.
- SDG&E (pub.)  
6875 Consolidated Way
- SDG&E (pvt.)  
3365 F St.
- Texaco (pub.)  
2445 Otay Center Dr.
- US Navy (pvt.)  
32nd St. Pub Works Cntr.

## San Francisco

- PG&E (Imtd.)  
536 Treat Ave.
- PG&E (Imtd.)  
19th and Shotwell
- S.F. City Corp. Yard (pvt.)
- S.F. Airport (Imtd.)  
692 McDonald Rd.

## Sanger

- Gibbs Cardlock (pub.)  
3555 So. Academy Ave.

## San José

- PG&E (Imtd.)  
308 Stockton Ave.

## San Luis Obispo

- San Luis Obispo USD (pub.)  
78 Prado Rd.

## San Pedro

- SoCal Gas (pub.)  
755 W. Capitol Dr.

## San Rafael

- PG&E (Imtd.)  
1220 Andersen Drive

## San Ramon

- UPS (pub.)  
4500 Norris Canyon Rd.
- PG&E Learning Center (Imtd.)

## Santa Ana

- L&N Uniform (pvt.)  
1602 E. Edinger
- Gold Coast Bakery (pvt.)  
1590-B E. Gertrude Pl.

## Santa Barbara

- Air Pollution Dist. (Imtd.)  
4430 Calle Real

## Santa Cruz

- PG&E (Imtd.)  
615 7th Ave.

## Santa Maria

- SoCal Gas (pub.)  
2310 S. Meredith Lane

## Santa Monica

- SoCal Gas (pub.)  
1701 Stewart Street
- GTE (pvt.)  
2943 Exposition Bl.

## Santa Rosa

- PG&E (Imtd.)  
3965 Occidental Rd.
- City of Santa Rosa (pvt.)
- Sonoma Transit (pvt.)

## Selma

- City of Selma (pvt.)

## South San Francisco

- Olympian Oil (pub.)  
190 E. Grand Ave.

## Stockton

- PG&E (pub.)  
4040 West Lane
- PG&E (pvt.)  
1001 W. Charter Way

## Sunnyvale

- Lockheed (pvt.)

## Sun Valley

- So. California MTA (pvt.)  
11900 Branford St.
- LA Unified SD (pub.)  
11247 Sherman Way

## Thousand Palms

- Sunline Transit (pub.)  
32-505 Harry Oliver Trail

## Torrance

- SoCal Gas (pub.)  
32-505 Harry Oliver Trail

## Vacaville

- PG&E (Imtd.)  
158 Peabody

## Van Nuys

- SoCal (pub.)  
16645 Satlicoy St.
- LA Dept Trans. (pvt.)  
5725 Sepulveda Bl.

## Vernon

- SoCal Gas (pvt.)  
2921 Leonis Bl.

## Vista

- UNOCAL (Imtd.)  
636 Sycamore St.
- Vista Unified SD (pvt.)

## Watsonville

- City Yard (pvt.)

## Woodland

- B.C. Stocking (pub.)  
341 Industrial Way

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**NOTE: Not all sites have full public access. Some are private; some have limited public access by arrangement with the local natural gas utility company. Please contact the local utility company in advance regarding specific locations.**

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## KEY

(pub.) = public access

(Imtd.) = limited access

(pvt.) = private, no access

# Chapter 11

## Where Do We Go From Here?

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The future is still uncertain when it comes to alternative fuels. Much work needs to be done at all levels to assure competition in the transportation fuel marketplace. Gasoline is going through a major change as California transitions to **reformulated** gasoline, and petroleum products will continue to be the dominant transportation fuel for many years (if not decades) to come. The Energy Commission forecasts, however, that by 2010, nearly 29 percent of the light-duty vehicles in California could be fueled by something other than gasoline or diesel. The Commission estimates that five million methanol-powered flexible fuel vehicles could be on the road, up to two million electric vehicles could be on the road, about one million natural gas vehicles could be on the road, and up to one-half million vehicles could be fueled by LPG. All combined, that means that more than ten million vehicles could be running on fuels other than gasoline or diesel by 2010.

To get there requires much work over the next 15 years. It also requires that fleets and fleet managers comply with current regulations to help the state realize its goals of cleaner skies and less dependency on petroleum. It requires education of fleet drivers and of the general public about clean, alternative fuels. It also requires cooperation between varying competing interests.

No one fuel is expected to be the “winner” over any other. Each of the fuels has its place in tomorrow’s energy picture...just like solar, wind, geothermal, nuclear and natural gas all have a place in producing California’s electricity. By using a number of different transportation fuels, California and its residents will be the “WINNERS.”

The state continues its private/public alliances with the establishment of the **California Alternative Fuel Vehicle Partnership**. Through discussion, teamwork, sharing of ideas and problems; and through the talents, resources and successes that California already enjoys...the state will move forward into the next decade.

For general information about alternative transportation fuels in California contact:

**California Energy Commission**  
Transportation Technology & Fuels Office  
1516 Ninth Street, MS-41  
Sacramento, CA 95814  
Phone: 916-654-4634

Also contact:  
**U.S. Department of Energy**  
National Alternative Fuels Hotline  
P.O. Box  
Arlington, VA 22209  
Phone: 1-800-423-1DOE

Other information about the various fuels can be obtained from the lists of organizations, fuel providers, companies and people at the end of each chapter.

**Our grand business is not to see what lies dimly in the distance,  
but to do what lies clearly at hand.**

**– Carlyle**



# Glossary

**AFTER-MARKET** – broad term that applies to any change after the original purchase, such as adding equipment not a part of the original purchase. As applied to alternative fuel vehicles, it refers to conversion devices or kits for conventional fuel vehicles.

**ALTERNATIVE FUELS** - as defined by the National Energy Policy Act (EPA) the fuels are: methanol, denatured ethanol and other alcohols, separately or in mixtures of 85 percent by volume or more (or other percentage not less than 70 percent as determined by U.S. Department of Energy rule) with gasoline or other fuels; CNG; LNG; LPG; hydrogen; “coal-derived liquid fuels;” fuels “other than alcohols” derived from “biological materials;” electricity, or any other fuel determined to be “substantially not petroleum” and yielding “substantial energy security benefits and substantial environmental benefits.”

**ALTERNATIVE FUEL VEHICLE (AFV)** – motor vehicles that run on fuels other than petroleum-based fuels. As defined by the National Energy Policy Act (EPA), this **excludes** reformulated gasoline as an alternative fuel.

**BI-FUEL VEHICLE** – a vehicle with two separate fuel systems designed to run on either fuel, using only one fuel at a time. These systems are advantageous for drivers who do not always have access to an alternative fuel refueling station. Bi-fuel systems are usually used in light-duty vehicles.

**BIODIESEL** – a biodegradable transportation fuel for use in diesel engines that is produced through the transesterification of organically-derived oils or fats. It may be used either as a replacement for or as a component of diesel fuel.

**BRITISH THERMAL UNIT (Btu)**– a standard unit for measuring heat energy. One Btu represents the amount of heat required to raise one pound of water one degree Fahrenheit (at sea level).

**CERTIFICATION** – process by which a motor vehicle, motor vehicle engine, or motor vehicle pollution control device satisfies the criteria adopted by the California Air Resources Board (ARB) for the control of specified air contaminants from vehicular sources (Health & Safety Code, Section 39018). Certification constitutes a guarantee by the manufacturer that the engine will meet certain standards at 50,000 miles; if not, it must be replaced or repaired without change.

**CLEAN FUEL VEHICLE** – is frequently incorrectly used interchangeably with “alternative fuel vehicle.” Generally, refers to vehicles that use low-emission, clean-burning fuels. Public Resources Code §25326 defines clean fuels, for purposes of the section only, as fuels designated by ARB for use in LEVs, ULEVs or ZEVs and include, but are not limited to, electricity, ethanol, hydrogen, liquefied petroleum gas, methanol, natural gas, and reformulated gasoline.

**CLUNKERS** – also known as gross-polluting or super-emitting vehicles, i.e., vehicles that emit far in excess of the emission standards by which the vehicle was certified when it was new.

**COMPRESSED NATURAL GAS (CNG)** – natural gas that has been compressed under high pressure, typically between 2,000 and 3,600 pounds per square inch, held in a container. The gas expands when released for use as a fuel.

**CONVERSION** – device or kit by which a conventional fuel vehicle is changed to an alternative fuel vehicle.

**CONVERTED VEHICLE** – a vehicle originally designed to operate on gasoline that has been modified or altered to run on an alternative fuel.

**CORPORATE AVERAGE FUEL ECONOMY (CAFE)** – a sales-weighted average fuel mileage calculation, in terms of miles per gallon, based on city and highway fuel economy measurements performed as part of the federal emissions test procedures. CAFE requirements were instituted by the Energy Policy and Conservation Act of 1975 (89 Statute. 902) and modified by the Automobile Fuel Efficiency Act of 1980 (94 Statute. 1821). For major manufacturers, CAFE levels are currently 27.5 miles per gallon for light-duty automobiles. CAFE standards also apply to some light trucks. The Alternative Motor Fuels Act of 1988 allows for an adjusted calculation of the fuel economy of vehicles that can use alternative fuels, including fuel-flexible and dual-fuel vehicles.

**DUAL-FUEL** refers to a vehicle with two separate fuel systems and operate on two different fuels at the same time. An example of a dual-fuel vehicle is a diesel/CNG truck that burns both fuels at the same time during certain conditions to reduce the overall emissions.

**E10 (Gasohol)** – a mixture of 10 percent ethanol, 90 percent unleaded gasoline.

**E85** – a mixture of 85 percent ethanol, 15 percent unleaded gasolines.

**ENERGY/FUEL DIVERSITY** – policy that encourages the development of energy technologies to diversify energy supply sources, thus reducing reliance on conventional (petroleum) fuels; applies to all energy sectors.

**ENERGY/FUEL SECURITY** – policy that considers the risk of dependence on fuel sources located in remote and unstable regions of the world and the benefits of domestic and diverse fuel sources.

**ETHANOL** (also known as Ethyl Alcohol or Grain Alcohol,  $\text{CH}_3\text{CH}_2\text{OH}$ ) – a liquid that is produced chemically from ethylene or biologically from the fermentation of various sugars from carbohydrates found in agricultural crops and cellulosic residues from crops or wood. Used in the United States as a gasoline octane enhancer and oxygenate, it increases octane 2.5 to 3.0 numbers at 10 percent concentration. Ethanol can also be used in higher concentration (E85) in vehicles optimized for its use.

**ETHYL TERTIARY BUTYL ETHER (ETBE)** – an aliphatic ether similar to MTBE. This fuel oxygenate is manufactured by reacting isobutylene with ethanol. Having high octane and low volatility characteristics, ETBE can be added to gasoline up to a level of approximately 17 percent by volume. ETBE is used as an oxygenate in some reformulated gasolines.

**EV (ELECTRIC VEHICLE)** – a vehicle powered by electricity, usually provided by batteries but may also be provided by photovoltaic (solar) cells or a fuel cell.

**FLEXIBLE FUEL VEHICLE (FFV)** – a vehicle that can operate on either alcohol fuels (methanol or ethanol) or regular unleaded gasoline or any combination of the two from the same tank.

**FUEL CELL** – an electrochemical engine with no moving parts that converts the chemical energy of a fuel, such as hydrogen, and an oxidant, such as oxygen, directly into electricity. The principal components of a fuel cell are catalytically activated electrodes for the fuel (anode) and the oxidant (cathode) and an electrolyte to conduct ions between the two electrodes, thus producing electricity.

**GASOHOL** – in the United States, gasohol (E10) refers to gasoline that contains 10 percent ethanol by volume. This term was used in the late 1970s and early 1980s but has been replaced in some areas of the country by terms such as E-10, Super Unleaded Plus Ethanol, or Unleaded Plus.

**HYBRID VEHICLE** – usually hybrid EVs, a vehicle which employs a combustion engine system together with an electric propulsion system. Hybrid technologies expand the usable range of EVs beyond what an all-electric-vehicle can achieve with batteries only.

**ILEV (Inherently Low Emission Vehicle)** – term used by federal government for any vehicle that is certified to meet the California Air Resources Board's Low Emission Vehicle standards for non-methane organic gases and carbon monoxide and ULEV standards for nitrogen oxides, and does not emit any evaporative emissions.

**INFRASTRUCTURE** – generally refers to the recharging and refueling network necessary to successful development, production, commercialization and operation of alternative fuel vehicles, including fuel supply, public and private recharging and refueling facilities, standard specifications for refueling outlets, customer service, education and training, and building code regulations.

**LEV (LOW EMISSION VEHICLE)** – a vehicle certified by the California Air Resources Board to have emissions from zero to 50,000 miles no higher than 0.075 grams/mile (g/mi) of non-methane organic gases, 3.4 g/mi of carbon monoxide, and 0.2 g/mi of nitrogen oxides. Emissions from 50,000 to 100,000 miles may be slightly higher (See chart in Chapter 2.)

**LNG (LIQUEFIED NATURAL GAS)** – natural gas that has been condensed to a liquid, typically by cryogenically cooling the gas to **minus** 327.2 degrees Fahrenheit (below zero).

**LPG (LIQUEFIED PETROLEUM GAS)** – a mixture of gaseous hydrocarbons, mainly propane and butane that change into liquid form under moderate pressure. LPG or propane is commonly used as a fuel for rural homes for space and water heating, as a fuel for barbecues and recreational vehicle, and as a transportation fuel. It is normally created as a by-product of petroleum refining and from natural gas production.

**M85** – a blend of 85 percent methanol and 15 percent unleaded regular gasoline, used as a motor fuel.

**M100** – 100 percent (neat) methanol used as a motor fuel in dedicated methanol vehicles, such as some heavy-duty truck engines.

**METHANE (CH<sub>4</sub>)** – the simplest of hydrocarbons and the principal constituent of natural gas. Pure methane has a heating value of 1,1012 Btu per standard cubic foot.

**METHANOL** (also known as Methyl Alcohol, Wood Alcohol, CH<sub>3</sub>OH) – a liquid formed by catalytically combining carbon monoxide (CO) with hydrogen (H<sub>2</sub>) in a 1:2 ratio, under high temperature and pressure. Commercially it is typically made by steam reforming natural gas. Also formed in the destructive distillation of wood.

**METHYL TERTIARY BUTYL ETHER (MTBE)** – an ether manufactured by reacting methanol and isobutylene. The resulting ether has a high octane and low volatility. MTBE is a fuel oxygenate and is permitted in unleaded gasoline up to a level of 15 percent. It is one of the primary ingredients in reformulated gasolines.

**NGV (NATURAL GAS VEHICLE)** – vehicles that are powered by compressed or liquefied natural gas.

**OFF-ROAD** – any non-stationary device, powered by an internal combustion engine or motor, used primarily off the highways to propel, move, or draw persons or property, and used in any of the following applications: marine vessels, construction/farm equipment, locomotives, utility and lawn and garden equipment, off-road motorcycles, and off-highway vehicles.

**ORIGINAL-EQUIPMENT MANUFACTURER (OEM)** – refers to the manufacturers of complete vehicles or heavy-duty engines, as contrasted with remanufacturers, converters, retrofitters, up-fitters, and repowering or rebuilding contractors who are overhauling engines, adapting or converting vehicles or engines obtained from the OEMs, or exchanging or rebuilding engines in existing vehicles.

**OXYGENATE** – a term used in the petroleum industry to denote octane components containing hydrogen, carbon and oxygen in their molecular structure. Includes ethers such as MTBE and ETBE and alcohols such as ethanol or methanol. The oxygenate is a prime ingredient in reformulated gasoline. The increased oxygen content given by oxygenates promotes more complete combustion, thereby reducing tailpipe emissions.

**PARTICULATE MATTER (PM)** – Unburned fuel particles that form smoke or soot and stick to lung tissue when inhaled. A chief component of exhaust emissions from heavy-duty diesel engines.

**PROPANE** – See LPG (Liquefied Petroleum Gas).

**RATE-BASING** – refers to practice by utilities of allotting funds invested in utility Research Development Demonstration and Commercialization and other programs from ratepayers, as opposed to allocating these costs to shareholders.

**REFORMULATED GASOLINE (RFG)** – a cleaner-burning gasoline that have had their compositions and/or characteristics altered to reduce vehicular emissions of pollutants.

**REID VAPOR PRESSURE (RVP)** – a standard measurement of a liquid's vapor pressure in pounds per square inch at 100 degrees Fahrenheit. It is an indication of the propensity of the liquid to evaporate.

**RETROFIT** – broad term that applies to any change after the original purchase, such as adding equipment not a part of the original purchase. As applied to alternative fuel vehicles, it refers to conversion devices or kits for conventional fuel vehicles. (Same as “aftermarket”.)

**TAME (TERTIARY AMYL METHYL ETHER)** – another oxygenate that can be used in reformulated gasoline. It is an ether based on reactive C<sub>5</sub> olefins and methanol.

**TLEV (TRANSITIONAL LOW EMISSION VEHICLE)** – a vehicle certified by the California Air Resources Board to have emissions from zero to 50,000 miles no higher than 0.125 grams/mile (g/mi) of non-methane organic gases, 3.4 g/mi of carbon monoxide, and 0.4 g/mi of nitrogen oxides. Emissions from 50,000 to 100,000 miles may be slightly higher (See chart in Chapter 2.)

**ULEV (ULTRA-LOW EMISSION VEHICLE)** – a vehicle certified by the California Air Resources Board to have emissions from zero to 50,000 miles no higher than 0.040 grams/mile (g/mi) of non-methane organic gases, 1.7 g/mi of carbon monoxide, and 0.2 g/mi of nitrogen oxides. Emissions from 50,000 to 100,000 miles may be slightly higher (See chart in Chapter 2.)

**WARRANTY** – seller's guarantee to purchaser that product is what it is represented to be and, if it is not, that it will be repaired or replaced. Within the context of vehicles, refers to an engine manufacturers guarantee that the engine will meet “certified” engine standards at 50,000 miles or the engine will be replaced. Retrofits will generally void an engine warranty.

**ZEV (ZERO EMISSION VEHICLE)** – any vehicle that is certified by the California Air Resources Board to have zero tailpipe emissions. The only vehicles that currently qualify as ZEVs are electric vehicles (EVs).

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